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(54) **CONTROL DEVICE FOR STEAM GOVERNING VALVE OF POWER GENERATION PLANT, AND METHOD FOR CONTROLLING STEAM GOVERNING VALVE OF POWER GENERATION PLANT**

(57) The objective of the present invention is to provide a technique for controlling a steam governing valve of a power generation plant capable of maintaining an active power output after recovery from a power system transient event. A control system (10) for a steam governing valve of a power generation plant is provided with a transient event detecting unit (48) which detects an occurrence of a power system transient event, and an opening degree correcting unit (110) which, during the occurrence of the power system transient event, maintains an opening degree of a steam governing valve (13) for adjusting an amount of steam flowing into a steam turbine (18) to be in the vicinity the opening degree when the power system transient event occurred.

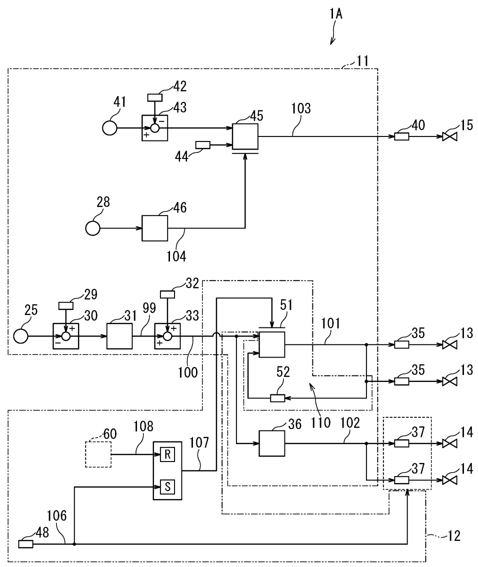

FIG. 2

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Description

TECHNICAL FIELD

[0001] Embodiments of the present invention relate to a control system for a steam governing valve of a power generation plant and a method for controlling a steam governing valve of a power generation plant.

BACKGROUND

[0002] Conventionally, there is known a technique for preventing step-out of a generator due to occurrence of a transient event in a power system or a valve control technique when the rotational speed of a turbine increases due to the occurrence of the transient event in the power system.

PRIOR ART DOCUMENT

PATENT DOCUMENT

[0003]

[Patent Document 1] JP S62-210204 A
[Patent Document 2] JP 2014-159744 A

SUMMARY

PROBLEMS TO BE SOLVED BY INVENTION

[0004] When the transient event in the power system occurs, the steam governing valve is controlled on the basis of increase or vibration of the turbine rotation speed and thereby this steam governing valve operates in the closing direction, and consequently, the pressure of steam flowing into the steam turbine drops sharply. Additionally, a bypass valve for allowing the steam to flow to a condenser may be opened during the transient event in the power system. Thus, there is a problem that the output of active power cannot be maintained after restoration of the power system from the transient event.

[0005] In view of the above-described problem, embodiments of the present invention aim to provide a control technology for a steam governing valve of a power plant capable of maintaining an output of active power after restoration of the power system from the transient event.

BRIEF DESCRIPTION OF DRAWINGS

[0006]

Fig. 1 is a configuration diagram illustrating an overall system of the power plant according to the first embodiment.
Fig. 2 is a block diagram illustrating a circuit of the pressurized water nuclear power plant according to the first embodiment.
Each of 3A to 3J is a timing chart during the transient event in the power system according to the first embodiment.
Fig. 4 is a flowchart illustrating a method for controlling steam governing valves of the first embodiment.
Fig. 5 is a configuration diagram illustrating a circuit of the pressurized water nuclear power plant according to the second embodiment.
Each of Fig. 6A to 6I is a timing chart during the transient event in the power system according to the second embodiment.
Fig. 7 is a flowchart illustrating a method for controlling the steam governing valves of the second embodiment.
Fig. 8 is a configuration diagram illustrating a circuit of the pressurized water nuclear power plant according to the third embodiment.
Fig. 9 is a flowchart illustrating a method for controlling the steam governing valves of the third embodiment.
Fig. 10 is a configuration diagram illustrating a circuit of the boiling water nuclear power plant according to the fourth embodiment.
Each of Fig. 11A to 11K is a timing chart during the transient event in the power system according to the fourth embodiment.
Fig. 12 is a flowchart illustrating a method for controlling the steam governing valves of the fourth embodiment.
Each of Fig. 13A to 13H is a timing chart during the transient event in the power system in the pressurized water nuclear power plant as a comparative example.
Each of Fig. 14A to 14I is a timing chart during the transient event in the power system in the boiling water nuclear power plant as a comparative example.

DETAILED DESCRIPTION

[0007] In one embodiment of the present invention, a control system for a steam governing valve of a power generation plant, the control system comprising:

a transient-event detector configured to detect occurrence of a transient event in a power system; and an opening-degree correction unit configured to maintain an opening degree of a steam governing valve to substantially same as an opening degree at a time of the occurrence of the transient event in the power system during the transient event in the power system, the steam governing valve being configured to adjust amount of steam flowing into a steam turbine.

(First Embodiment)

[0008] Hereinbelow, embodiments will be described by referring to the accompanying drawings. First, a description will be given of a control system for steam governing valves of a power generation plant according to the first embodiment by referring to Fig. 1 to Fig. 4. The reference sign 1 in Fig. 1 indicates the power generation plant 1.

[0009] First, a system configuration related to a turbine control system of a pressurized water nuclear power plant will be described as one aspect of the power generation plant 1 by referring to Fig. 1. The reference sign 16 denotes a steam generator. In the pressurized water reactor, the steam generator 16 generates steam by heat exchange with the primary coolant introduced from the reactor vessel. In a thermal power plant, the heat source of the steam generator 16 is replaced with a boiler or an exhaust heat recovery boiler. In a boiling water nuclear plant described below, the steam generator 16 is a reactor pressure vessel. Other system configurations are the same.

[0010] The steam generated by the steam generator 16 is led to a high-pressure turbine 18 as a steam turbine. The steam discharged from the high-pressure turbine 18 flows into a low-pressure turbine 19 via moisture separation heaters 17. The high-pressure turbine 18 and the low-pressure turbine 19 are rotated, and the rotational force of them causes a generator 20 to generate electricity.

[0011] The steam generated by the steam generator 16 is inputted to the high-pressure turbine 18. The thermal energy of this steam is converted into kinetic energy, and thereby the generator 20 is driven. On the input side of the high-pressure turbine 18, steam governing valves 13 for adjusting the amount of steam flowing into the turbine 18 are provided. The steam governing valves 13 control the inflow amount of steam to be inputted into the high-pressure turbine 18. Although two steam governing valves 13 are provided in the configuration shown in Fig. 1, the number of the steam governing valves 13 is not limited to specific number.

[0012] Each moisture separation heater 17 is a device that removes the moisture content of the steam exhausted from the high-pressure turbine 18, heats it, and inputs it to the low-pressure turbine 19. Each moisture separation heater 17 may be a device that only separates moisture or a device that only heats steam.

[0013] The steam to be outputted from the moisture separation heaters 17 is inputted to the low-pressure turbine 19. The thermal energy of this steam is converted into kinetic energy, and thereby the generator 20 is driven. The low-pressure turbine 19 outputs low-pressure turbine exhaust. On the input side of the low-pressure turbine 19, intercept valves 14 are provided. The intercept valves 14 regulate the flow rate of the steam to be exhausted from the moisture separation heaters 17. The intercept valves 14 control the inflow amount of the steam to be inputted into the low-pressure turbine 19. Although two intercept valves 14 are provided in the configuration shown in Fig. 1, the number of the intercept valves 14 is not limited to specific number.

[0014] The generator 20 converts the kinetic energy of the turbine to be generated by the high-pressure turbine 18 and the low-pressure turbine 19 into electric energy.

[0015] The low-pressure turbine exhaust outputted from the low-pressure turbine 19 is condensed by the condenser 21, and then is returned to the steam generator 16 via a condenser pump 22 and a condensate pump 23.

[0016] The power generation plant 1 includes a bypass valve 15 that allows excessive steam to flow directly into the condenser 21 when the amount of the steam generated by the steam generator 16 becomes larger than the amount of the steam flowing into the turbine. The bypass valve 15 controls the amount of excessive steam to be inputted from the steam generator 16 into the condenser 21. Although one bypass valve 15 is provided in the configuration shown in Fig. 1, the number of the bypass valves 15 is not limited to specific number.

[0017] The control system 10 of the steam governing valves 13 of the power generation plant 1 includes a normal control circuit 11 and an early valve actuating control circuit 12. Although details of the normal control circuit 11 and the early valve actuating control circuit 12 will be described below, the outline is as follows.

[0018] The control system 10 is connected to the central control system 3 installed in the central control room 2 of the power generation plant 1. The central control system 3 includes: an operation unit 4 that can be operated by an operator of the power generation plant 1; and a display 5 that displays information related to an operation, monitoring, and management of the power generation plant 1. Although the central control system 3 and the control system 10 are illustrated as separately in Fig. 1 to facilitate understanding, both may be integrated.

[0019] The power generation plant 1 is provided with a turbine-rotation-speed detector 25 that detects the rotation speed of each of the high-pressure turbine 18 and the low-pressure turbine 19. The turbine rotation speed detected by this turbine-rotation-speed detector 25 is inputted to the normal control circuit 11. An opening degree of each of the steam governing valves 13 and the intercept valves 14 is adjusted such that the turbine rotation speed becomes a predetermined value having been set by a rotation-speed setter 29 (Fig. 2). Then, the amount of the steam flowing into each valve is controlled. The "opening degree" may be simply referred to as the "opening".

[0020] In this manner, the normal control circuit 11 controls the turbine rotation speed during normal operation, at the time of start, and at the time of stop.

[0021] The early valve actuating control circuit 12 controls opening/closing of the intercept valves 14 in priority to the control by the normal control circuit 11 when the transient event in the power system occurs. The transient event in the power system is a phenomenon which occurs when, for example, an accident in which one or some of many power transmission lines extending from the power generation plant 1 is cut and grounded. The transient event in the power system may refer to an event in which the voltage drops significantly for a very short time to an event in which a relatively small voltage drop occurs for a long time. However, the transient event in the power system event here means a phenomenon in which the period from its occurrence to its restoration is 1 second or less.

[0022] In the following description, time of the occurrence of the transient event in the power system indicates the time point at which the normal condition is switched to the transient event in the power system. The term "during the occurrence of the transient event in the power system" indicates the period during which the transient event in the power system continues. The restoration time of the power system from transient event indicates the time point at which the power system is switched from the transient event to the normal condition. The time of the occurrence of the transient event in the power system may include the period immediately before the occurrence of the transient event in the power system.

[0023] Fig. 2 shows a specific configuration of the normal control circuit 11 in the pressurized water nuclear power plant 1A according to the first embodiment. The same components as the components in Fig. 1 are indicated by the same reference signs.

[0024] The turbine-rotation-speed detector 25 detects the rotation speed of the turbine. The turbine-rotation-speed detector 25 outputs the detection signal to a deviation calculator 30. The deviation calculator 30 subtracts the inputted detection signal and the speed signal having been preset in the rotation-speed setter 29, and outputs the subtracted signal to a multiplier 31. The multiplier 31 obtains a speed control signal 99 by multiplying this subtracted signal by a gain (i.e., the reciprocal of the speed adjustment rate). Instead of the multiplier 31, PI control may be performed only during turbine startup control.

[0025] Further, an adder 33 calculates a speed load control signal 100 by adding the speed control signal 99 and the load setting value having been set by a load setter 32. The speed load control signal 100 is outputted to servo valves 35 as a steam-governing-valve opening-degree command-signal 101. The opening degree of the steam governing valves 13 is adjusted by changing the supply amount of control oil by the servo valves 35.

[0026] The speed load control signal 100 calculated from the adder 33 is outputted to a multiplier 36. The multiplier 36 obtains an intercept-valve opening-degree command-signal 102 by multiplying the speed load control signal 100 by a gain. The intercept-valve opening-degree command-signal 102 is outputted to servo valves 37. The opening degree of the intercept valves 14 is adjusted by changing the supply amount of the control oil by the servo valves 37.

[0027] The bypass valve 15 is installed in order to reduce the pressure rise in the steam generator 16 or the reactor. The bypass valve 15 is controlled so as to open at the time of the occurrence of the transient event, such as a sudden decrease in turbine load or a plant trip.

[0028] At normal times, in order to prevent disturbance of the increase in load on the steam generator 16 due to malfunction of the opening/closing control of the bypass valve 15, an interlock is provided for the opening control of the bypass valve 15 by the bypass-valve open permission signal 104.

[0029] When the output of the bypass-valve open permission signal 104 is off, the zero output of a signal generator 44 is prioritized by a switch 45 and the bypass valve is fully closed. When a turbine-load sudden-change detection-circuit 46 determines that sudden change in the turbine load has occurred as detected by the turbine load detector 28, the bypass-valve open permission signal 104 is outputted.

[0030] As a conceivable method for detecting sudden change in turbine load, there is a method for focusing on the fluctuation of the first-stage steam pressure or the fluctuation of the generator current (for example, threshold determination using the amount of change in target parameter per unit time). When the bypass-valve open permission signal 104 is outputted, the switch 45 controls the opening degree of the bypass valve 15 by the deviation signal of the bypass-valve control-target process calculated by a deviation calculator 43 on the basis of the setting values having been set in a process detector 41 and a process setter 42.

[0031] The process value to be controlled by the bypass valve 15 may be, for example, the primary cooling-system temperature and the secondary-side steam pressure.

[0032] The control operation during the rated operation of the pressurized water nuclear power plant will be described by referring to Fig. 2.

[0033] During the rated operation, the turbine rotation speed is controlled by adjusting the opening degree of the steam governing valves 13 and the intercept valves 14 on the basis of the speed load control signal 100. That is, control is performed on the basis of the speed control value that is changed in relation to the rotation speeds of the turbines 18 and 19.

[0034] At the time of the rated operation, the output of the bypass-valve open permission signal 104 is in the off state, so the switch 45 of the bypass-valve control circuit outputs zero and the bypass valve 15 becomes in the fully closed state. When the turbine load changes suddenly, the bypass-valve open permission signal 104 is outputted and the opening-degree control of the bypass valve 15 is started on the basis of the process value of the target of the bypass valve control.

[0035] In this manner, the normal control circuit 11 controls the turbine rotation speed by adjusting the opening degree of each of the steam governing valves 13 and the intercept valves 14.

[0036] Next, regarding the turbine early valve actuating control, the early valve actuating control circuit 12 will be described. In the power generation plant 1 connected to the power system, in the steady state, active power is being outputted from the generator 20 so as to match the mechanical input from the high-pressure turbine 18 and the low-pressure turbine 19.

[0037] However, in the power system, there may be occurrence of the transient event in which the active power to be outputted by the generator 20 decreases sharply, such as a sudden decrease in system voltage. Even if this transient event occurs, this transient event will be restored within 1 second. However, during this transient event, the turbine mechanical input exceeds the active power that can be sent to the power system. Thus, if the turbine rotation speed is increased and exceeds a certain limit, the generator 20 may goes step-out.

[0038] In order to prevent weakening of the power system, the power system side is required to continue the operation without causing the step-out. After the restoration of the power system from transient event, the system voltage required by the power system is also restored, so it is necessary to quickly recover the active power to be outputted from the generator 20 to the required value of the power system.

[0039] The turbine early valve actuating control is known as a method for preventing step-out and restoring active power quickly in the generator 20 when the transient event occurs in the power system. In the early valve actuating control circuit 12, a power-system transient-event detector 48 detects the transient event in the power system. When a power-system transient-event detection-signal 106 is outputted on the basis of this detection, the intercept valves 14 for causing the steam to flow into the low-pressure turbine 19 are rapidly closed. Further, the increase in turbine rotation speed is suppressed by temporarily blocking the flow of the steam into the low-pressure turbine 19. Moreover, after the restoration of the power system from the transient event, the intercept valves 14 are rapidly and fully opened to recover the active power quickly. The timing to open the intercept valves 14 rapidly does not have to coincide with the transient event reset. For example, as soon as the opening degree of the intercept valves 14 reaches 0%, they may be opened.

[0040] As shown in Fig. 2, in the early valve actuating control circuit 12, the power-system transient-event detector 48 detects the transient event in the power system and outputs the power-system transient-event detection-signal 106.

[0041] Depending on the output of the power-system transient-event detection-signal 106, a steam-governing-valve opening-degree correction-command signal 107 is outputted. Thereafter, the opening-degree correction control of the steam governing valves 13 is started. The opening degree of the steam governing valves 13 is corrected so as to become close to the predetermined opening degree at the time of the occurrence of the transient event in the power system.

[0042] The problem of the conventional technique (i.e., the event in which the opening degree of the steam governing valves 13 tends to close due to the speed control depending on the vibration of the turbine speed immediately after the transient event in the power system) can be prevented by the opening-degree correction control of the steam governing valves 13. More specifically, the event in which the valves tends to close means that the opening degree of the valves continues to be lower than necessary due to difference in opening/closing speed of the valves despite the fact that both the command signal to open the valves and the command signal to close the valves are alternately transmitted after the occurrence of the transient event in the power system.

[0043] As a result, the amount of steam at the predetermined opening degree of the steam governing valves 13 can be supplied to the turbine, whereas the amount of steam flowing into the turbine is reduced in the conventional technique. Thus, prompt response to the restoration of active power required after the restoration of the power system from the transient event can be achieved. Additionally, adverse effects on the steam generation side such as increase in steam pressure due to the tendency of the steam governing valves 13 to close can be avoided.

[0044] In the opening-degree correction control of the steam governing valves 13, for example, the opening degree of the steam governing valves 13 is corrected to the predetermined opening degree by the following method.

[0045] Next, as a specific aspect of the opening-degree correction control of the steam governing valves 13 in the first embodiment, a description will be given of a method for holding the input of the steam-governing-valve opening-degree command-signal 101 at the value at the time of the occurrence of the transient event in the power system.

[0046] As shown in Fig. 2, in the first embodiment, during the opening-degree correction control of the steam governing valves 13, an opening-degree correction unit 110 is provided for holding the steam-governing-valve opening-degree command-signal 101 at the time of the occurrence of the transient event in the power system.

[0047] This opening-degree correction unit 110 includes: a switch 51 that can switch between the speed load control signal 100 and the steam-governing-valve opening-degree command-signal 101; and a signal holder 52 configured to hold the steam-governing-valve opening-degree command-signal 101, which is information indicating the opening degree of the steam governing valves 13, during normal time before the occurrence of the transient event in the power system.

[0048] The opening degree held in the signal holder 52 is the opening degree at the time of occurrence of the transient event in the power system, and the switch 51 is a component for switching the opening degree of the steam governing valves 13 to the opening degree held in the signal holder 52 during the transient event in the power system. The signal holder 52 is a memory that stores the value included in the steam-governing-valve opening-degree command-signal 101.

[0049] In this manner, the opening degree at the time of the occurrence of the transient event in the power system is held in the signal holder 52. Thus, during the transient event in the power system, the opening degree of the steam governing valves 13 can be maintained at the opening degree at the time of the occurrence of the transient event in the power system on the basis of the opening degree held in the signal holder 52.

[0050] When the steam-governing-valve opening-degree correction-command signal 107 is off, the switch 51 outputs the speed load control signal 100 normally. When the steam-governing-valve opening-degree correction-command signal 107 is on, the value at the time of the occurrence of the transient event in the power system held in the signal holder 52 is outputted as the steam-governing-valve opening-degree command-signal 101.

[0051] When the reset of the steam-governing-valve opening-degree correction control is determined by a steam-governing-valve opening-degree correction control reset circuit 60, a steam-governing-valve opening-degree correction-command reset signal 108 is outputted from the steam-governing-valve opening-degree correction control reset circuit 60 and the output of the steam-governing-valve opening-degree correction-command signal 107 is turned off.

[0052] The reset of the steam-governing-valve opening-degree correction control is performed by the steam-governing-valve opening-degree correction control reset circuit 60 as shown in Fig. 2. When the steam-governing-valve opening-degree correction control is continued until the vibration of the turbine rotation speed is settled, as one aspect of the reset condition of the steam-governing-valve opening-degree correction-command signal 107, there is a conceivable method in which the power-system transient-event detection-signal 106 is turned off and the steam-governing-valve opening-degree correction-command reset signal 108 is outputted after determining settling of the turbine speed. As a method for detecting the settling of the turbine speed, for example, it is conceivable to: perform threshold determination of the peak value of damping vibration due to the transient event of turbine speed; determine whether the peak value is no longer observed or not; and perform threshold determination of deviation of the absolute value of vibration per unit time.

[0053] If the steam-governing-valve opening-degree correction control is switched to the normal control during vibration of the turbine rotation speed, the steam governing valves 13 may tend to close. However, the steam governing valve opening-degree correction control is reset after settling the vibration of the turbine rotation speed, which avoids the event that the steam governing valve 13 tends to close, and thus the decrease in steam amount available at the time of restoration of the active power can be avoided.

[0054] In other words, the maintenance of the opening degree of the steam governing valves 13 by the opening-degree correction unit 110 is completed when both of the restoration of the power system from the transient event and the settling of the rotation speeds of the steam turbines 18 and 19 are fulfilled. In this manner, when both of the restoration of the power system from the transient event and the settling of the rotation speeds of the steam turbines 18 and 19 are satisfied, the system can be returned to the normal control.

[0055] The effects of the first embodiment will be described by using the timing chart shown in Fig. 3A to Fig. 3J. Fig. 3A is a timing chart showing the power-system transient-event detection-signal 106. Fig. 3B is a timing chart showing the steam-governing-valve opening-degree correction-command signal 107. Fig. 3C is a timing chart showing the turbine rotation speed. Fig. 3D is a timing chart showing the speed load control signal 100. Fig. 3E is a timing chart showing the steam-governing-valve opening-degree command-signal 101. Fig. 3F is a timing chart showing the opening degree of the steam governing valves 13. Fig. 3G is a timing chart showing the opening degree of the intercept valves 14. Fig. 3H is a timing chart showing the bypass-valve open permission signal 104. Fig. 3I is a timing chart showing the opening degree of the bypass valve 15. Fig. 3J is a timing chart showing the pressure of the steam generator 16. In Fig. 3, T1 indicates the time point at which the transient event in the power system occurs, T2 indicates the time point at which the power system is restored from the transient event, and T3 indicates the time point at which the steam-governing-valve opening-degree correction-command is reset.

[0056] When the transient event in the power system occurs, the intercept valves 14 are rapidly closed (Fig. 3G). Although the turbine speed once rises due to the occurrence of the transient event in the power system, the turbine speed begins to fall because steam is not supplied to the low-pressure turbine due to the rapid closure of the intercept valves 14. Further, though the intercept valves 14 are closed, the turbine speed vibrate so as to converge to the rated output (Fig. 3C) because the power system is restored from the transient event and the load is returned. Note that the pressure of the moisture separation heaters 17 temporarily rises due to the closing of the intercept valves 14.

[0057] Although vibration of the turbine rotation speed (Fig. 3 C) is the cause of making the steam governing valves 13 tend to close at the time of occurrence of the transient event in the power system, the steam-governing-valve opening-degree correction-command signal 107 is outputted, and thus the speed load control signal 100 (Fig. 3 D) in accordance with the vibration of the turbine rotation speed is excluded from the input of the steam-governing-valve opening-degree command-signal 101. Hence, the steam-governing-valve opening-degree command-signal 101 maintains the value at the time of the occurrence of the transient event in the power system (Fig. 3E).

[0058] Consequently, the opening degree of the steam governing valves 13 is also maintained at the predetermined opening degree at the time of the occurrence of the transient event in the power system (Fig. 3F).

[0059] In the first embodiment, during the transient event in the power system, the opening degree of the steam governing valves is maintained at the value at the time of the occurrence of the transient event in the power system without being affected by the vibration of the turbine rotation speed. Thus, decrease in steam amount at the time of restoration of the power system from the transient event can be avoided.

[0060] In addition, the pressure of the steam generator 16 is maintained at the value at the time of the occurrence of the transient event in the power system (Fig. 3J). Thus, the disturbance to the system due to the fluctuation of the steam pressure can be suppressed as much as possible. Further, with the reset of the steam-governing-valve opening-degree correction-command signal 107, the steam-governing-valve opening-degree command-signal 101 restarts the normal control by the speed load control signal 100.

[0061] Since the turbine rotation speed continues to vibrate even after the steam-governing-valve opening-degree correction command is reset in the case shown in Fig. 3, the steam governing valves 13 repeatedly open and close a little after shifting to the normal control by the speed load control signal 100.

[0062] Next, as a comparative example, a description will be given of a case where the opening-degree of the steam governing valves 13 is adjusted and the bypass valve 15 is operated during the transient event in the power system without performing the opening-degree correction control, by using the timing chart shown in Fig. 13. Fig. 13 is a timing chart illustrating the opening-degree operation of the steam governing valves 13, the bypass valve 15, and the intercept valves 14 when the transient event in the power system occurs in the pressurized water nuclear power plant 1A as the comparative example.

[0063] Fig. 13A is a timing chart showing the power-system transient-event detection-signal 106. Fig. 13B is a timing chart showing the turbine rotation speed. Fig. 13C is a timing chart showing the speed load control signal 100 and the steam-governing-valve opening-degree command-signal 101. Fig. 13D is a timing chart showing the opening degree of the steam governing valves 13. Fig. 13E is a timing chart showing the opening degree of the intercept valves 14. Fig. 13F is a timing chart showing the bypass-valve open permission signal 104. Fig. 13G is a timing chart showing the opening degree of the bypass valve 15. Fig. 13H is a timing chart showing the pressure of the steam generator 16. In Fig. 13, T1 indicates the time point at which the transient event in the power system occurs and T2 indicates the time point at which the power system is restored from the transient event.

[0064] When the transient event in the power system occurs at T1, the early valve actuating control circuit 12 operates so as to rapidly close the intercept valves 14 (Fig. 13E). At this time, the amount of the steam flowing into the low-pressure turbine 19 is temporarily greatly reduced.

[0065] Generally, the opening-degree control based on the steam-governing-valve opening-degree command-signal 101 is continued for the steam governing valves 13, similarly to the normal control. Immediately after the turbine early valve actuating control, deviation occurs between the turbine rotation speed and the turbine speed setting value in the rotation-speed setter 29 due to the vibration of the turbine rotation speed (Fig. 13B). Thus, the opening-degree control of the steam governing valves 13 is performed on the basis of the speed load control signal 100 and the steam-governing-valve opening-degree command-signal 101 (Fig. 13C) according to the turbine rotation speed.

[0066] However, due to the mechanical design for rapidly closing the steam governing valves 13 as a protective action, the closing speed of the valves is faster than the opening speed. Thus, the opening degree of the steam governing valves 13 tends to be closed (Fig. 13D).

[0067] Since the turbine load suddenly changes due to the occurrence of the transient event in the power system, the bypass-valve open permission signal 104 is outputted and the bypass valve 15 is opened (Fig. 13F and Fig. 13G), which causes the steam before entering the high-pressure turbine 18 to flow out to the condenser 21. For safety design, the bypass valve 15 is designed to be opened rapidly. Thus, as to the effect on the steam flow rate, increase in flow rate by opening the bypass valve 15 is larger than decrease in flow rate by closing the steam governing valves 13. Hence, the amount of the steam flowing out from the steam generator 16 increases and the pressure of the steam generator 16 decreases (Fig. 13H). This reduces the amount of the steam flowing into the high-pressure turbine 18 at the time of the restoration of the power plant from the transient event (T2). Consequently, the output of active power cannot be maintained after the restoration of the power system from the transient event.

[0068] Contrastively, according to the present embodiment, the pressure of the steam generator 16 is maintained as shown in Fig. 3J, and thus the output of active power can be maintained immediately after the restoration of the power system from the transient event.

[0069] The control system of the present embodiment includes hardware resources such as a processor and a memory and is configured as a computer in which information processing by software is achieved with the use of the hardware resources by causing the CPU to execute various programs. Further, the method for controlling the steam governing valves 13 of the power generation plant 1 of the present embodiment is achieved by causing the computer to execute the various programs.

[0070] Next, the processing to be executed by the control system 10 will be described by using the flowchart of Fig. 4. This processing is repeated at regular intervals.

When this processing is repeated, the control method for the steam governing valves 13 of the power generation plant 1 is executed by the control system 10. Note that this processing may be interrupted and executed while the control system 10 is executing other main processing.

[0071] First, in the step S11, the control system 10 determines whether the opening-degree correction unit 110 is maintaining the opening degree of the steam governing valves 13 at the opening degree at the time of the occurrence of the transient event in the power system or not. If the opening-degree correction unit 110 is maintaining the opening degree of the steam governing valves 13 at the opening degree at the time of the occurrence of the transient event in the power system (YES in the step S11), the processing proceeds to the step S15 described below. Conversely, if the opening-degree correction unit 110 is not maintaining the opening degree of the steam governing valves 13 at the opening degree at the time of the occurrence of the transient event in the power system (NO in the step S11), the processing proceeds to the step S12.

[0072] In the step S12, the control system 10 determines whether the transient event in the power system is detected by the power-system transient-event detector 48 or not. If the transient event in the power system is detected (YES in the step S12), the processing proceeds to the step S16 described below. Conversely, if the transient event in the power system is not detected (NO in the step S12), the processing proceeds to the step S13.

[0073] In the step S13, the control system 10 adjusts the opening degree of the steam governing valves 13 by the steam-governing-valve opening-degree command-signal 101.

[0074] In the next step S14, the signal holder 52 holds the steam-governing-valve opening-degree command-signal 101, and then the processing is completed.

[0075] In the step S15, the control system 10 determines whether the reset conditions are satisfied or not. The reset conditions are that the power system is restored from the transient event and the turbine speed is settled. If the reset conditions are satisfied (YES in the step S15), the processing proceeds to the step S17 described below. Conversely, if the reset conditions are not satisfied (NO in the step S15), the processing proceeds to the step S16.

[0076] In the step S16, the control system 10 maintains the opening degree of the steam governing valves 13 at the opening degree at the time of the occurrence of the transient event in the power system by using the opening-degree correction unit 110, and then the processing is completed.

[0077] In the step S17, the control system 10 adjusts the opening degree of the steam governing valves 13 by the steam-governing-valve opening-degree command-signal 101, and then the processing is completed.

(Second Embodiment)

[0078] Next, a description will be given of the control system 10 for the steam governing valves 13 of the power generation plant 1 according to the second embodiment by referring to Fig. 5 to Fig. 7. The same reference signs are assigned to the same components as the above-described embodiment, and duplicate description is omitted.

[0079] Fig. 6A is a timing chart showing the power-system transient-event-detection-signal 106. Fig. 6B is a timing chart showing the steam-governing-valve opening-degree correction-command signal 107. Fig. 6C is a timing chart showing the turbine rotation speed. Fig. 6D is a timing chart showing the speed load control signal 100 and the steam-governing-valve opening-degree command-signal 101. Fig. 6E is a timing chart showing the opening degree of the steam governing valves 13. Fig. 6F is a timing chart showing the opening degree of the intercept valves 14. Fig. 6G is a timing chart showing the bypass-valve open permission signal 104. Fig. 6H is a timing chart showing the opening degree of the bypass valve 15. Fig. 6I is a timing chart showing the pressure of the steam generator 16. In Fig. 6, T1 indicates the time point at which the transient event in the power system occurs, T2 indicates the time point at which the power system is restored from the transient event, and T3 indicates the time point at which the steam-governing-valve opening-degree correction-command is reset.

[0080] In the second embodiment, the opening speed and closing speed of the steam governing valves 13 are matched during the steam-governing-valve opening-degree correction control. This control corrects the difference in opening/closing speed that causes the steam governing valves 13 to tend to close.

[0081] Normally, the closing speed of the steam governing valves 13 is faster than the opening speed of the steam governing valves 13. As a method for matching the opening speed and closing speed of the steam governing valves 13, there are conceivable methods of: multiplying the steam-governing-valve opening-degree command-signal 101 by a gain with the use of an opening-degree correction unit 111; and correcting the output of the servo valve 35 that drives the steam governing valves 13.

[0082] Although the closing speed of the steam governing valves 13 is faster than opening speed of the steam governing valves 13, the opening-degree correction unit 111 of the second embodiment performs correction processing by which the closing speed of the steam governing valves 13 is brought close to the opening speed, during the transient event in the power system. In other words, the opening-degree correction unit 111 performs correction processing so as to slow down the closing speed of the steam governing valves 13. In this manner, the opening degree of the steam governing valves 13, which operates in the direction of closing during the transient event in the power system, can be maintained to substantially same as the opening degree at the time of the occurrence of the transient event in the power system.

[0083] At this time, speed control is performed on the steam governing valves 13 on the basis of on the steam-governing-valve opening-degree command-signal 101 (Fig. 6D) that is depending on the vibration of the turbine rotation speed (Fig. 6C). However, the above-described opening-degree correction unit 111 is used to make the opening speed and the closing speed of the steam governing valves 13 the same, so that the steam governing valves 13 are controlled so as to be near the predetermined opening degree (Fig. 6E). Thus, the opening degree of the steam governing valves 13 can be corrected so as to be near the predetermined opening degree while the speed control is being maintained.

[0084] In the second embodiment, the speed control for the vibration of the turbine rotation speed is performed, and thus, the opening degree of the steam governing valves 13 is controlled so as to be near the predetermined opening degree. Although the amount of steam used at the time of restoration of active power is reduced in the conventional technique, in the second embodiment, the reduction in the amount of steam can be avoided.

[0085] Next, the processing to be executed by the control system 10 will be described by using the flowchart of Fig. 7. This processing is repeated at regular intervals. When this processing is repeated, the control method for the steam governing valves 13 of the power generation plant 1 is executed by the control system 10. Note that this processing may be interrupted and executed while the control system 10 is executing other main processing.

[0086] First, in the step S21, the control system 10 determines whether the opening-degree correction unit 111 is correcting the closing speed of the steam governing valves 13 or not. If the opening-degree correction unit 111 is correcting the closing speed of the steam governing valves 13 (YES in the step S21), the processing proceeds to the step S24 described below. Conversely, If the opening-degree correction unit 111 is not correcting the closing speed of the steam governing valves 13 (NO in the step S21), the processing proceeds to the step S22.

[0087] In the step S22, the control system 10 determines whether the transient event in the power system is detected by the power-system transient-event detector 48 or not. If the transient event in the power system is detected (YES in the step S22), the processing proceeds to the step S25 described below. Conversely, if the transient event in the power system is not detected (NO in the step S22), the processing proceeds to the step S23.

[0088] In the step S23, the control system 10 adjusts the opening degree of the steam governing valves 13 by the steam-governing-valve opening-degree command-signal 101, and then the processing is completed.

[0089] In the step S24, the control system 10 determines whether the reset conditions are satisfied or not. The reset conditions are that the power system is restored from the transient event and the turbine speed is settled. If the reset conditions are satisfied (YES in the step S24), the processing proceeds to the above-described step S23. Conversely, if the reset conditions are not satisfied (NO in the step S24), the processing proceeds to the step S25.

[0090] In the step S25, the control system 10 corrects the closing speed of the steam governing valves 13 by using the opening-degree correction unit 111, and then the processing is completed.

(Third Embodiment)

[0091] Next, a description will be given of the control system 10 for the steam governing valves 13 of the power generation plant 1 according to the third embodiment on the basis of Fig. 8 and Fig. 9 by referring to Fig. 3 as required. The same reference signs are assigned to the same components as the above-described embodiments, and duplicate description is omitted.

[0092] In the configurations shown in Fig. 2 and Fig. 5, there is a possibility that the bypass valve 15 opens while the steam-governing-valve opening-degree correction-command signal 107 is being outputted. However, in the configuration shown in Fig. 8, the bypass-valve open permission signal 104 is forcibly controlled to be off while the steam-governing-valve opening-degree correction-command signal 107 is being outputted. That is, the bypass-valve open permission signal 104 is disabled (invalidated).

[0093] The configuration of the third embodiment includes a bypass-valve full-closing control-circuit 113 configured to disable the signal of controlling the bypass valve 15, which is to be opened when the steam before entering the turbines 18 and 19 is bypassed to the condenser 21, during the transient event in the power system.

[0094] With such a configuration, the bypass valve 15 is maintained in the fully closed state even at the time of the occurrence of the transient event in the power system (Fig. 3H and Fig. 3I). Thus, the steam outflow to the condenser 21 can be prevented. Further, the pressure of the steam generator 16 is maintained at the value at the time of the occurrence of the transient event in the power system (Fig. 3 J). In other words, the closed state of the bypass valve can be maintained during the transient event in the power system, and thus, decrease in amount of the steam flowing into the turbines 18 and 19 can be prevented. This configuration can avoid decrease in amount of the steam available at the time of restoration of active power after the restoration of the power system from the transient event.

[0095] Further, as shown in Fig. 8, steam outflow to the condenser 21 can be avoided by forcibly turning off the bypass-valve open permission signal 104. When it is necessary to avoid adverse effects such as pressure increase in the steam generator 16, pressure control of the steam generator 16 can also be performed by controlling the opening degree of the steam governing valves 13 with the bypass valve 15 fully closed.

[0096] As one aspect of the pressure control method for the steam generator 16, there is a conceivable method in which an open bias is provided in the steam governing valves 13 by using an adder 54 for adding a predetermined value having been set in a pressure control setter 53 to the steam-governing-valve opening-degree command-signal 101. In the pressure control according to the third embodiment, the pressure control setter 53 and the adder 54 constitute a control adjustment circuit. This control adjustment circuit is a part of the opening degree correction unit in the third embodiment. The predetermined value may be a pressure signal detected by a pressure detector 24 or may be a value based on a constant opening degree corresponding to opening of the bypass valve.

[0097] Consequently, the above-describe configuration can suppress the disturbance that adversely affects the system, such as excessive pressure rise on the equipment side for generating the steam, while avoiding decrease in amount of the steam to be used at the time of restoration of active power after restoration of the power system from the transient event.

[0098] Although the bypass valve 15 is opened when the steam before entering the high-pressure turbine 18 is bypassed to the condenser 21, the closed state of the bypass valve 15 is maintained during the transient event in the power system in the third embodiment. Further, the configuration of the third embodiment includes the control adjustment circuit for adjusting the control value that controls the steam governing valves 13 on the basis of the pressure of the steam generator 16 with the bypass valve 15 kept closed. In this manner, the steam generator 16 can be prioritized over the high-pressure turbine 18 during the transient event in the power system, so that its soundness can be maintained.

[0099] The reset of the steam-governing-valve opening-degree correction control is performed by the steam-governing-valve opening-degree correction control reset circuit 60 as shown in Fig. 8. When the steam governing valve opening-degree correction control is continued until the vibration of the turbine rotation speed is settled, as reset conditions of the steam-governing-valve opening-degree correction command signal 107, there is a conceivable method of outputting the steam-governing-valve opening-degree correction-command reset signal 108 when the power-system transient-event detection-signal 106 is turned off and the settling of the turbine speed is determined by the turbine-speed settling detector 55. As a method of causing the turbine-speed settling detector 55 to detect the settling, for example, there are conceivable methods of: (i) performing threshold determination on the peak value of damping vibration caused by the transient event of turbine speed; (ii) determining whether the peak value is no longer observed; and (iii) performing threshold determination on the deviation of the absolute value of vibration per unit time.

[0100] When it is switched from the steam-governing-valve opening-degree correction control to the normal control during the vibration of the turbine rotation speed, there is a possibility that the steam governing valves 13 tend to close. However, when the steam-governing-valve opening-degree correction control is reset after settling the vibration of the turbine rotation speed, the event that the steam governing valves 13 tend to close can be avoided, and decrease in amount of steam available at the time of restoration of active power can be avoided.

[0101] Additionally, the forced-off of the steam-governing-valve opening-degree correction control and the bypass-valve open permission signal 104 can be manually switched on or off by an operator operating the manual operation switch 56. As a result, the plant can be operated after the operator determines the necessity of the steam-governing-valve opening-degree correction control and the bypass-valve full-closing maintenance control. The manual operation switch 56 is provided in the operation unit 4 of the central control system 3.

[0102] In a period during which the steam-governing-valve opening-degree correction-command signal 107 is outputted, the operation monitoring display 57 can display that the forced off function of the steam-governing-valve opening-degree correction control and the bypass-valve open permission signal 104 is enabled. As a result, when the steam-governing-valve opening-degree correction control and the bypass-valve full-closing maintenance control are activated, the operator can be informed of it promptly, which contributes to improvement in operation monitor ability. Incidentally, the operation monitoring display 57 is provided on the display 5 of the central control system 3.

[0103] When the opening degree of the steam governing valves 13 is maintained to substantially same as the opening degree at the time of the occurrence of the transient event in the power system, this display 5 informs the operator of the power generation plant 1 of the above-described fact that the opening degree is maintained. In this manner, the operator of the power generation plant 1 can be notified of the fact that the opening degree of the steam governing valves 13 is maintained.

[0104] Next, a description will be given of the processing to be executed by the control system 10 of the present embodiment in association with the bypass-valve open permission signal 104, by using the flowchart of Fig. 9. This processing is repeated at regular intervals. When this processing is repeated, the control method for the steam governing valves 13 of the power generation plant 1 is executed by the control system 10. Note that this processing may be interrupted and executed while the control system 10 is executing other main processing.

[0105] First, in the step S31, the control system 10 determines whether the bypass-valve open permission signal 104 is disabled by the bypass-valve full-closing control-circuit 113 or not. If the bypass-valve open permission signal 104 is disabled (YES in the step S31), the processing proceeds to the step S34 described below.

Conversely, if the bypass-valve open permission signal 104 is not disabled (NO in the step S31), the processing proceeds to the step S32.

[0106] In the step S32, the control system 10 determines whether the transient event in the power system is detected by the power-system transient-event detector 48 or not. If the transient event in the power system is detected (YES in the step S32), the processing proceeds to the step S35 described below. Conversely, if the transient event in the power system is not detected (NO in the step S32), the processing proceeds to the step S33.

[0107] In the step S33, the control system 10 validates (enables) the bypass-valve open permission signal 104, and then the processing is competed.

[0108] In the step S34, the control system 10 determines whether the reset conditions are satisfied or not. The reset conditions are that the power system is restored from the transient event and the turbine speed is settled. If the reset conditions are satisfied (YES in the step S34), the processing is completed. Conversely, if the reset conditions are not satisfied (NO in the step S34), the processing proceeds to the step S35.

[0109] In the step S35, the control system 10 disables the bypass-valve open permission signal 104 by using the bypass-valve full-closing control-circuit 113, and then the processing is completed.

(Fourth Embodiment)

[0110] Next, a description will be given of the control system 10 for the steam governing valves 13 of the power generation plant 1 according to the fourth embodiment by referring to Fig. 10 to Fig. 12. The same reference signs are assigned to the same components as the above-described embodiments, and duplicate description is omitted. In the fourth embodiment, an embodiment in the boiling water nuclear power plant 1B will be described below.

[0111] Fig. 10 illustrates a detailed configuration of the normal control circuit 11 in the boiling water nuclear power plant 1B. The same components as those in Fig. 1 and Fig. 2 are denoted by the same reference signs, and there is no change in the functions except the matters described below.

[0112] During the rated operation in the boiling water nuclear power plant 1B, the normal control circuit 11 performs reactor-pressure constant control with priority over the turbine rotation speed control. When the turbine speed is near the rated speed, opening-degree control of the steam governing valves 13 is performed such that the reactor pressure is kept constant by controlling the reactor pressure. That is, control is performed on the basis of the pressure control value that is changed in relation to the reactor pressure.

[0113] When the turbine rotation speed become significantly higher than the rotation-speed setter 29, the control method of the steam governing valves 13 is switched from the reactor pressure control to the turbine rotation speed control and the valve opening degree is controlled in the closing direction. At this time, the opening degree of the bypass valve 15 is controlled in the opening direction, and thereby the amount of the steam flowing into the high-pressure turbine 18 and the condenser 21 is adjusted such that the reactor pressure is controlled to a constant value. The detailed operation is as follows.

[0114] The pressure detector 24 detects the pressure in the steam generator 16 and outputs a detection signal to a deviation calculator 27. The deviation calculator 27 subtracts the inputted detection signal and the pressure setting value having been preset in a pressure setter 26, and outputs a pressure deviation signal to a multiplier 38. The multiplier 38 calculates the total steam-flow-rate command-signal 105 by multiplying the pressure deviation signal by a gain (i.e., reciprocal of the pressure regulation rate).

[0115] This total steam-flow-rate command-signal 105 indicates the steam flow rate that is necessary to keep the pressure of the steam generator 16 constant and is the steam flow rate to be outputted from the reactor. A low value selector 34 selects the signal having the lowest value from the steam amount values when the turbine is rotationally controlled by the speed represented by the total steam-flow-rate command-signal 105 and the speed load control signal 100, and then outputs the selected signal as the steam-governing-valve opening-degree command-signal 101. That is, of the speed control value based on the rotation speed of the high-pressure turbine 18 and the pressure control value based on the pressure of the steam generator 16, the lower value is selected so that the steam governing valves 13 are controlled on the basis of the selected lower value.

[0116] Further, the deviation calculator 39 calculates the bypass-valve flow-rate command-signal 103 on the basis of the deviation between the total steam-flow-rate command-signal 105 and the steam-governing-valve opening-degree command-signal 101. The bypass-valve flow-rate command-signal 103 is outputted to a servo valve 40. The servo valve 40 changes the supply amount of the control oil, and thereby the valve opening degree of the bypass valve 15 is adjusted.

[0117] Next, a description will be given of a control operation at the time of the rated operation in the boiling water nuclear power plant 1B. During the rated operation, the value of the load setter 32 is generally set to a predetermined value larger than the actual load such that pressure control is prioritized. Further, in the low value selector 34, the total steam-flow-rate command-signal 105 is selected, and the reactor pressure control is performed by adjusting the opening degree of the steam governing valves 13.

[0118] At this time, the total steam-flow-rate command-signal 105 matches the steam-governing-valve opening-degree command-signal 101, so the bypass-valve flow-rate command-signal 103, which is the output of deviation calculator 39, becomes zero. Thus, the bypass valve 15 is fully closed. However, when the turbine rotation speed is excessively increased and the speed load control signal 100 outputted from the adder 33 is selected in the low value selector 34, the opening degree of the steam governing valves 13 is narrowed down and it shifts to the turbine rotation speed control. That is, control based on the speed control value is performed.

[0119] At this time, the decrement of steam amount narrowed down by the steam governing valves 13 is outputted from the deviation calculator 39 as the difference between the total steam-flow-rate command-signal 105 and the steam-governing-valve opening-degree command-signal 101. Further, the bypass valve 15 is controlled in the opening direction. In other words, excessive steam generated by narrowing down the steam governing valves 13 is made to flow into the condenser 21 via the bypass valve 15 in order to keep the reactor pressure constant. In this manner, the reactor pressure control is performed by the bypass valve 15. That is, control based on the pressure control value is performed.

[0120] In the fourth embodiment, the steam-governing-valve opening-degree correction control is performed depending on the output of the steam-governing-valve opening-degree correction-command signal 107 similarly to the above-described embodiments.

[0121] In the fourth embodiment, as a control method for the steam governing valves 13 when the turbine rotation speed significantly increases during the transient event in the power system, the control based on the reactor pressure control is performed without switching it to the turbine rotation speed control. Further, the opening degree of the steam governing valves 13 is corrected so as to be near the predetermined opening degree at the time of the occurrence of the transient event in the power system.

[0122] In this manner, the system can avoid the closing control of the steam governing valves 13 and the opening control of the bypass valves 15, both of which is in association with the increase in turbine rotation speed at the time of the occurrence of the transient event in the power system. The fourth embodiment obtains the same effects as those of the above-described embodiments and has the same functions except for the matters described below.

[0123] In the fourth embodiment, even when the turbine rotation speed is significantly increased, an opening-degree correction unit 112 is provided for correcting the input value selected as the steam-governing-valve opening-degree command-signal 101. This opening-degree correction unit 112 includes a switch 58 and a bias signal setter 59. In the fourth embodiment, the bias signal setter 59 is a bias circuit that increases the speed control value during the transient event in the power system.

[0124] In a period during which the steam-governing-valve opening-degree correction-command signal 107 is off, the switch 58 outputs the value having been set by the load setter 32 to the adder 33. In a period during which the steam-governing-valve opening-degree correction-command signal 107 is on, the switch 58 outputs a predetermined setting value having been set by the bias signal setter 59 to the adder 33.

[0125] As one aspect of the setting value to be set in the bias signal setter 59, there is a method of setting the maximum value of the rotational speed that can be generated.

[0126] Fig. 11A is a timing chart showing the power-system transient-event detection-signal 106. Fig. 11B is a timing chart showing the steam-governing-valve opening-degree correction-command signal 107. Fig. 11C is a timing chart showing the turbine rotation speed. Fig. 11D is a timing chart showing the output of the switch 58 for load setting. Fig. 11E is a timing chart showing the speed load control signal 100. Fig. 11F is a timing chart showing the total steam-flow-rate command-signal 105. Fig. 11G is a timing chart showing the steam-governing-valve opening-degree command-signal 101. Fig. 11H is a timing chart showing the opening degree of the steam governing valves 13. Fig. 11I is a timing chart showing the opening degree of the intercept valves 14. Fig. 11J is a timing chart showing the opening degree of the bypass valve 15. Fig. 11K is a timing chart showing the pressure of the steam generator 16. In Fig. 11, T1 indicates the time point at which the transient event in the power system occurs, T2 indicates the time point at which the power system is restored from the transient event, and T3 indicates the time point at which the steam-governing-valve opening-degree correction-command is reset.

[0127] Since a predetermined setting value is outputted from the switch 58 at the time of the occurrence of the transient event in the power system (Fig. 11D), the speed load control signal 100 is always set to a value larger than the total steam-flow-rate command-signal 105 (Fig. 11E and Fig. 11F).

[0128] The steam-governing-valve opening-degree command-signal 101 is a signal that takes the lower value of the speed load control signal 100 and the total steam-flow-rate command-signal 105. Thus, also at the time of the occurrence of the transient event in the power system, the total steam-flow-rate command-signal 105 is selected similarly to the normal control (Fig. 11G). Further, the reactor pressure control is continued. Hence, even at the time of the occurrence of the transient event in the power system, the opening degree of the steam governing valves 13 is maintained near the predetermined opening degree (Fig. 11H).

[0129] Additionally, the total steam-flow-rate command-signal 105 is selected as the steam-governing-valve opening-degree command-signal 101 in the steam governing valve opening-degree correction control, and thereby the bypass-valve flow-rate command-signal 103 becomes zero. Consequently, even at the time of the occurrence of the transient event in the power system, the bypass valve 15 is maintained in the fully closed state (Fig. 11 J). Since steam outflow to the condenser 21 is prevented, the reactor pressure can be maintained at the value at the time of occurrence of the transient event in the power system (Fig. 11K) .

[0130] Next, as a comparative example, a description will be given of a case where the opening-degree adjustment of the steam governing valves 13 and the operation of the bypass valve 15 are performed during the transient event in the power system without performing the opening-degree correction control, by using the timing chart shown in Fig. 14. Fig. 14 shows a timing chart when the transient event in the power system occurs in the boiling water nuclear power plant 1B as a comparative example.

[0131] Fig. 14A is a timing chart showing the power-system transient-event detection-signal 106. Fig. 14B is a timing chart showing the turbine rotation speed. Fig. 14C is a timing chart showing the speed load control signal 100. Fig. 14D is a timing chart showing the total steam-flow-rate command-signal 105. Fig. 14E is a timing chart showing the steam-governing-valve opening-degree command-signal 101. Fig. 14F is a timing chart showing the opening degree of the steam governing valves 13. Fig. 14G is a timing chart showing the opening degree of the intercept valves 14. Fig. 14H is a timing chart showing the opening degree of the bypass valve 15. Fig. 14I is a timing chart showing the pressure of the steam generator 16. In Fig. 14, T1 indicates the time point at which the transient event in the power system occurs, and T2 indicates the time point at which the power system is restored from the transient event.

[0132] Of the speed load control signal 100 (Fig. 14C) and the total steam-flow-rate command-signal 105 (Fig. 14D), the signal having the lower value is selected as the steam-governing-valve opening-degree command-signal 101 (Fig. 14E) in the boiling water nuclear power plant 1B.

[0133] Immediately after starting the turbine early valve actuating control from the occurrence (T1) of the transient event in the power system, the speed load control signal 100 is fluctuated (Fig. 14C) depending on increase and vibration of the turbine rotation speed (Fig. 14B).

[0134] When the turbine rotation speed is significantly increased, the speed load control signal 100 (Fig. 14C) has a smaller value than the total steam-flow-rate command-signal 105 (Fig. 14D). Thus, the speed load control signal 100 is selected as the steam-governing-valve opening-degree command-signal 101 (Fig. 14E) and the steam governing valves 13 are controlled so as to be closed (Fig. 14F).

[0135] In response to the closing control of the steam governing valves 13, the bypass valve 15 is controlled so as to open by the control based on the reactor pressure (Fig. 14H). Further, the steam before flowing into the high-pressure turbine 18 is discharged to the condenser 21, and the pressure of the steam generator 16 and the pressure of the reactor are reduced (FIG. 14I). Thus, at the time of restoration from the transient event (T2), the amount of the steam flowing into the high-pressure turbine 18 is reduced. With this reduced steam flow, the output of active power cannot be maintained after the restoration of the power system from the transient event.

[0136] In the fourth embodiment, even when the turbine rotation speed increases at the time of the occurrence of the transient event in the power system, the reactor pressure control is continued by the steam governing valves 13, the opening degrees of both of the steam governing valves 13 and the bypass valve 15 are controlled so as to be near the opening degree at the time of the occurrence of the transient event in the power system. Thus, in the fourth embodiment, decrease in amount of steam to be used at the time of restoration of active power can be avoided and disturbance to the system such as increase in steam pressure can be suppressed. Further, the reactor pressure control can be continued, and thus, stable and highly accurate control of the reactor pressure can be realized.

[0137] In the fourth embodiment, even during the turbine early valve actuating control, the reactor pressure control is prioritized, the steam governing valves 13 keep the predetermined opening degree and the bypass valve 15 keeps the fully closed state, which prevent steam outflow to the condenser 21. When the reactor pressure vessel is adversely affected, the opening degree of the steam governing valves 13 is adjusted and the pressure of the reactor pressure vessel is controlled under the state where the bypass valve 15 is fully closed. This control enables the system to: secure the amount of steam to be used at the time of the restoration of active power after the restoration of the power system from the transient event; and suppress disturbance that adversely affects the system, such as pressure fluctuation on the steam generator side.

[0138] In this manner, even when the turbine speed increases during the transient event in the power system, the pressure control value based on the pressure of the steam generator 16 has priority over the speed control value based on the rotation speed of the turbines 18 and 19, and is used for controlling the steam governing valves 13. Thus, the pressure of the steam generator 16 can be maintained appropriately. The closed state of the bypass valve 15, which is to be opened when the steam before being flowing into the turbine 18 is bypassed to the condenser 21, can be maintained.

[0139] Next, the processing to be executed by the control system 10 will be described by using the flowchart of Fig. 12. This processing is repeated at regular intervals. When this processing is repeated, the control method for the steam governing valves 13 of the power generation plant 1 is executed by the control system 10. Note that this processing may be interrupted and executed while the control system 10 is executing other main processing.

[0140] First, in the step S41, the control system 10 determines whether the correction for increasing the speed control value is performed by the opening-degree correction unit 112 or not. If the correction for increasing the speed control value is performed by the opening-degree correction unit 112(YES in the step S41), the processing proceeds to the step S44 described below. Conversely, if the correction for increasing the speed control value is not performed by the opening-degree correction unit 112 (NO in the step S41), the processing proceeds to the step S42.

[0141] In the step S42, the control system 10 determines whether the transient event in the power system is detected by the power-system transient-event detector 48 or not. If the transient event in the power system is detected (YES in the step S42), the processing proceeds to the step S45 described below. Conversely, if the transient event in the power system is not detected (NO in the step S42), the processing proceeds to the step S43.

[0142] In the step S43, the control system 10 adjusts the opening degree of the steam governing valves 13 by the steam-governing-valve opening-degree command-signal 101, and then the processing is completed.

[0143] In the step S44, the control system 10 determines whether the reset conditions are satisfied or not. The reset conditions are that the power system is restored from the transient event and the turbine speed is settled. If the reset conditions are satisfied (YES in the step S44), the processing proceeds to the above-described step S43. Conversely, if the reset conditions are not satisfied (NO in the step S44), the processing proceeds to the step S45.

[0144] In the step S45, the control system 10 performs the correction for increasing the speed control value by using the opening-degree correction unit 112. Thereafter, the processing proceeds to the above-described step S43.

[0145] Although "the control system for the steam governing valve of the power generation plant" according to the possible embodiments has been described on the basis of the first to fourth embodiments, the configuration applied in any one of the embodiments may be applied to other embodiments and the configurations applied in each embodiment may be used in combination.

[0146] For example, though the bypass-valve full-closing control-circuit 113 disables the signal of controlling the bypass valve 15 during the transient event in the power system in the third embodiment as described above, this configuration of the bypass-valve full-closing control-circuit 113 in the third embodiment may be applied to the first and second embodiments. The configurations of the operation monitoring display 57 and the manual operation switch 56 of the third embodiment may be applied to the first, second, and fourth embodiments.

[0147] Although a mode in which each step is executed in series is illustrated in the flowcharts of the present embodiment, the execution order of the respective steps is not necessarily fixed and the execution order of part of the steps may be changed. Additionally, some steps may be executed in parallel with another step.

[0148] The control system of the present embodiment includes a storage device such as a ROM (Read Only Memory) and a RAM (Random Access Memory), an external storage device such as an HDD (Hard Disk Drive) and an SSD (Solid State Drive), a display device such as a display panel, an input device such as a mouse and a keyboard, a communication interface, and a controller which has a highly integrated processor such as a special-purpose chip, an FPGA (Field Programmable Gate Array), a GPU (Graphics Processing Unit), and a CPU (Central Processing Unit). The control system can be achieved by hardware configuration with the use of a normal computer.

[0149] Note that each program executed in the control system of the present embodiment is provided by being incorporated in a memory such as a ROM in advance. Additionally or alternatively, each program may be provided by being stored as a file of installable or executable format in a non-transitory computer-readable storage medium such as a CD-ROM, a CD-R, a memory card, a DVD, and a flexible disk (FD).

[0150] In addition, each program executed in the control system may be stored on a computer connected to a network such as the Internet and be provided by being downloaded via a network. Further, the control system can also be configured by interconnecting and combining separate modules, which independently exhibit respective functions of the components, via a network or a dedicated line.

[0151] The control system 10 may include a restoration determination unit configured to determine whether the power system is restored from the generated transient event within 1 second or not. If the power system is not restored from the transient event within 1 second, the power system may be configured such that the opening-degree correction units 110, 111, 112 do not correct the opening degree of the steam governing valves 13. Additionally, if the power system is not restored from the transient event within 1 second, the bypass valve 15 may be opened or power generation of the power generation plant 1 may be stopped. Although the description has been given of the case where it is determined whether the restoration is completed within 1 second or not (i.e., 1 second is used as the determination threshold value), a predetermined time shorter than 1 second may be set as the determination threshold value.

[0152] According to at least one embodiment as described above, the opening-degree correction unit is provided for maintaining the opening degree of the valves to substantially same as the opening degree at the time of the occurrence of the transient event in the power system during the transient event, and thus, output of active power can be maintained after the restoration of the power system from the transient event.

[0153] While certain embodiments have been described, these embodiments have been presented by way of example only, and are not intended to limit the scope of the inventions. Indeed, the novel embodiments described herein may be embodied in a variety of other forms; furthermore, various omissions, substitutions and changes in the form of the embodiments described herein may be made without departing from the framework of the inventions. The above-cited invention and their equivalents are intended to cover such forms or modifications as would fall within the scope of the inventions.

Claims

1. A control system for a steam governing valve of a power generation plant, the control system comprising:

a transient-event detector configured to detect occurrence of a transient event in a power system; and
an opening-degree correction unit configured to maintain an opening degree of a steam governing valve to substantially same as an opening degree at a time of the occurrence of the transient event in the power system during the transient event in the power system, the steam governing valve being configured to adjust amount of steam flowing into a steam turbine.

2. The control system for a steam governing valve of a power generation plant according to claim 1, wherein the opening-degree correction unit is configured to maintain the opening degree of the steam governing valve at the opening degree at a time of the occurrence of the transient event in the power system, during the transient event in the power system.

3. The control system for a steam governing valve of a power generation plant according to claim 2, wherein the opening-degree correction unit includes:

a holder configured to hold information indicating the opening degree of the steam governing valve; and
a switch configured to switch the opening degree of the steam governing valve to the opening degree held by the holder during the transient event in the power system, the opening degree held by the holder being the opening degree at a time of the occurrence of the transient event in the power system.

4. The control system for a steam governing valve of a power generation plant according to claim 1, wherein the opening-degree correction unit is configured to perform correction to bring a closing speed of the steam governing valve closer to an opening speed of the steam governing valve during the transient event in the power system, the closing speed being faster than the opening speed.

5. The control system for a steam governing valve of a power generation plant according to any one of claim 1 to claim 4, further comprising a bypass-valve full-closing control-circuit configured to disable a signal of controlling a bypass valve during the transient event in the power system, the bypass valve being to be opened when steam before flowing into the steam turbine is bypassed to a condenser.

6. The control system for a steam governing valve of a power generation plant according to claim 1, wherein:

the steam governing valve is controlled according to a lower value of a speed control signal based on a rotation speed of the steam turbine and a pressure control value based on pressure of a steam generator; and
the opening-degree correction unit includes a bias circuit that increases the speed control value during the transient event in the power system.

7. The control system for a steam governing valve of a power generation plant according to any one of claim 1 to claim 6, wherein:

a closed state of a bypass valve is maintained during the transient event in the power system, the bypass valve being to be opened when steam before flowing into the steam turbine is bypassed to a condenser; and
the opening-degree correction unit is configured to adjust a control value for controlling the steam governing valve based on pressure of a steam generator under a state where the closed state of the bypass valve is maintained.

8. The control system for a steam governing valve of a power generation plant according to any one of claim 1 to claim 7, wherein maintaining of the opening degree of the steam governing valve by the opening-degree correction unit is completed when both of restoration of the power system from the transient event and settling of a rotation speed of the steam turbine are satisfied.

9. The control system for a steam governing valve of a power generation plant according to any one of claim 1 to claim 8, further comprising an operation unit that can be operated by an operator of the power generation plant,
wherein on/off switching control of maintaining the opening degree of the steam governing valve to substantially same as the opening degree at a time of the occurrence of the transient event in the power system is performed based on an operation on the operation unit.

10. The control system for a steam governing valve of a power generation plant according to any one of claim

1 to claim 9, further comprising a display, wherein, when the opening degree of the steam governing valve is maintained to substantially same as the opening degree at a time of occurrence of the transient event in the power system as a maintenance state by the opening-degree correction unit, the display is configured to notify an operator of the power generation plant of the maintenance state.

11. The control system for a steam governing valve of a power generation plant according to any one of claim 1 to claim 10, wherein the power generation plant comprises:

a steam generator configured to generate steam;
a high-pressure turbine configured as a steam turbine into which steam generated in the steam generator flows;
the steam governing valve configured to adjust amount of steam flowing into the high-pressure turbine from the steam generator;
a low-pressure turbine into which steam discharged from the high-pressure turbine and lower in pressure than steam flowing into the high-pressure turbine flows;
a generator configured to generate electricity by rotational force of the high-pressure turbine and the low-pressure turbine;
a condenser configured to condense steam to be discharged from the low-pressure turbine;
a bypass valve configured to be opened when steam before flowing into the high-pressure turbine is bypassed to the condenser; and
a control system that controls at least the steam governing valve and includes an early valve actuating control circuit and a normal control circuit configured to control the steam governing valve during a normal operation,
wherein the early valve actuating control circuit is provided with the opening-degree correction unit and is configured to control the steam governing valve during the transient event having a period within 1 second from occurrence to restoration in the power system.

12. A method for controlling a steam governing valve of a power generation plant comprising:

detecting occurrence of a transient event in a power system; and
maintaining an opening degree of a steam governing valve to substantially same as an opening degree at a time of the occurrence of the transient event in the power system during the transient event in the power system, the steam governing valve being configured to adjust amount of steam flowing into a steam turbine.

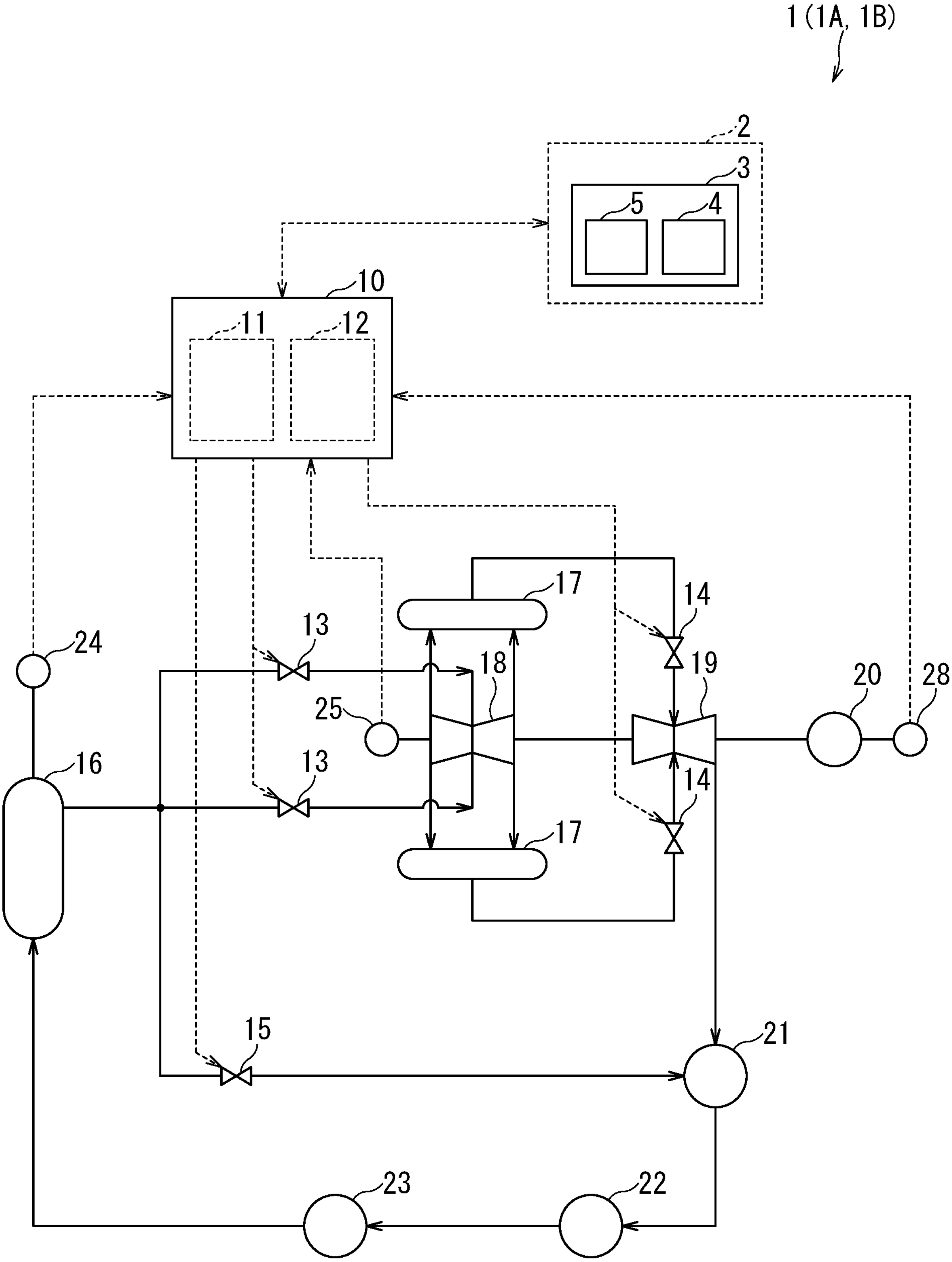
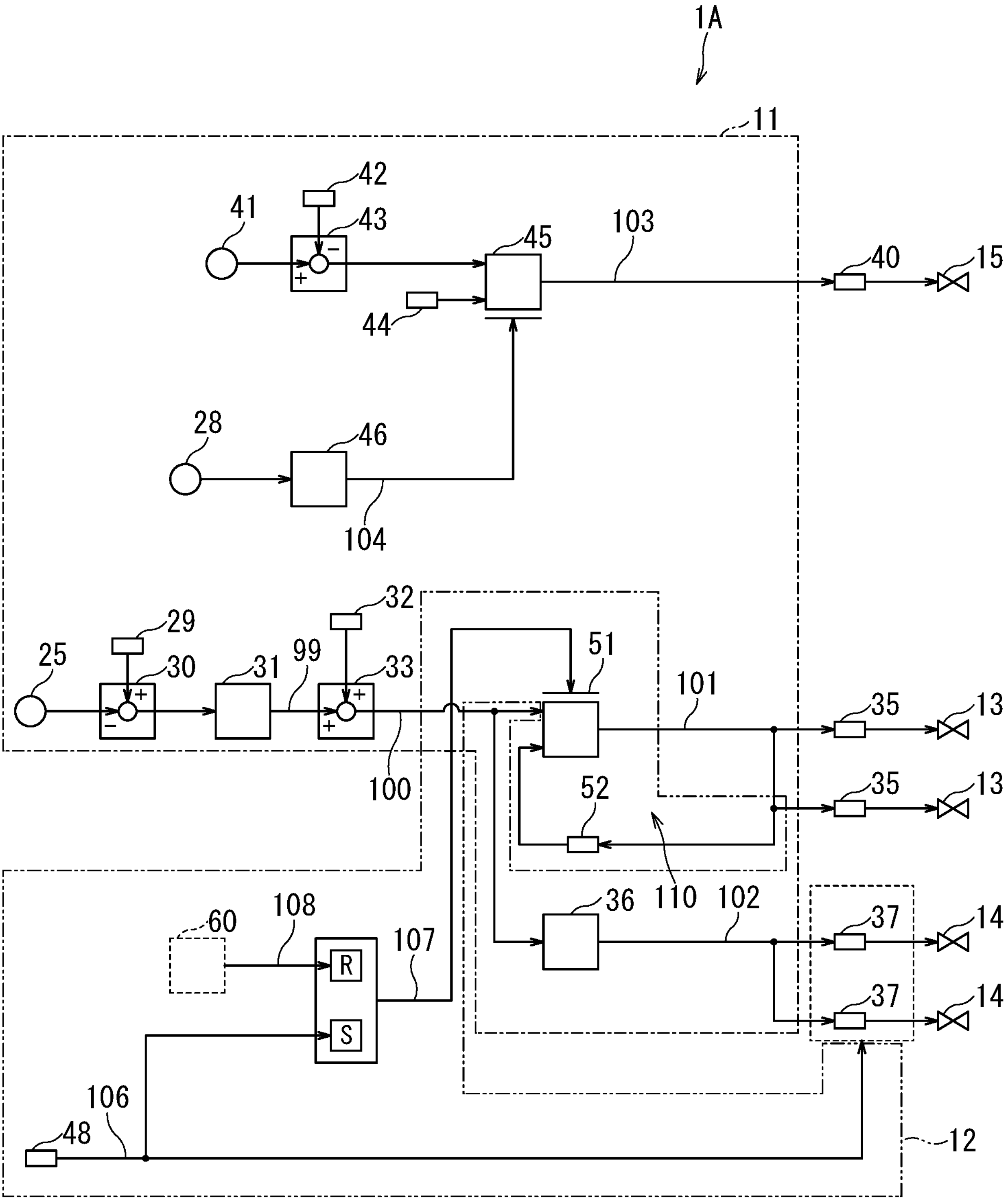


FIG. 1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35
13
100
35
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110
102
60
108
36
37
14
107
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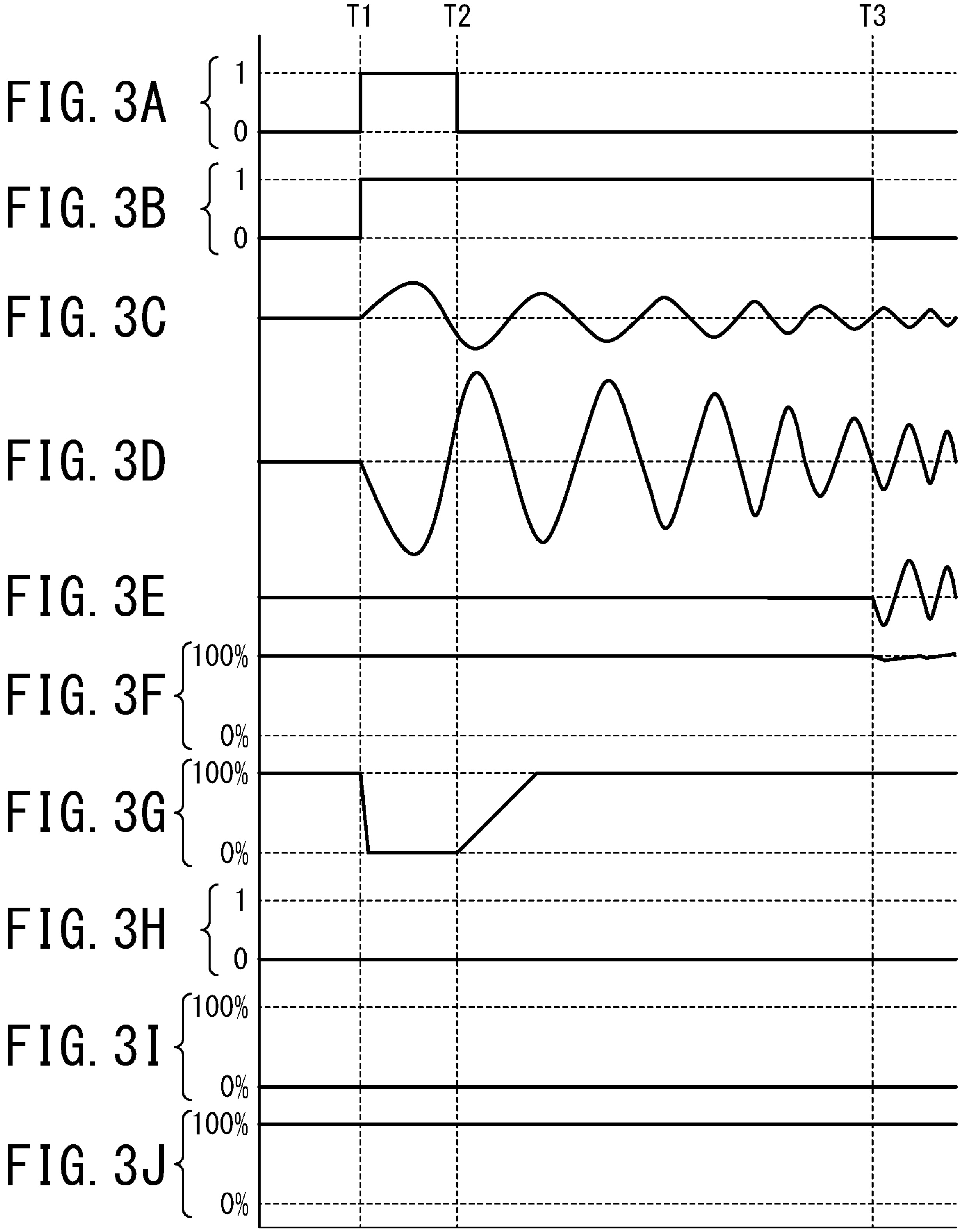
106
48
12

FIG. 2


T1
T2
T3
FIG. 3A
1
0
FIG. 3B
1
0
FIG. 3C
FIG. 3D
FIG. 3E
FIG. 3F
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0%
FIG. 3G
100%
0%
FIG. 3H
1
0
FIG. 3I
100%
0%
FIG. 3J
100%
0%

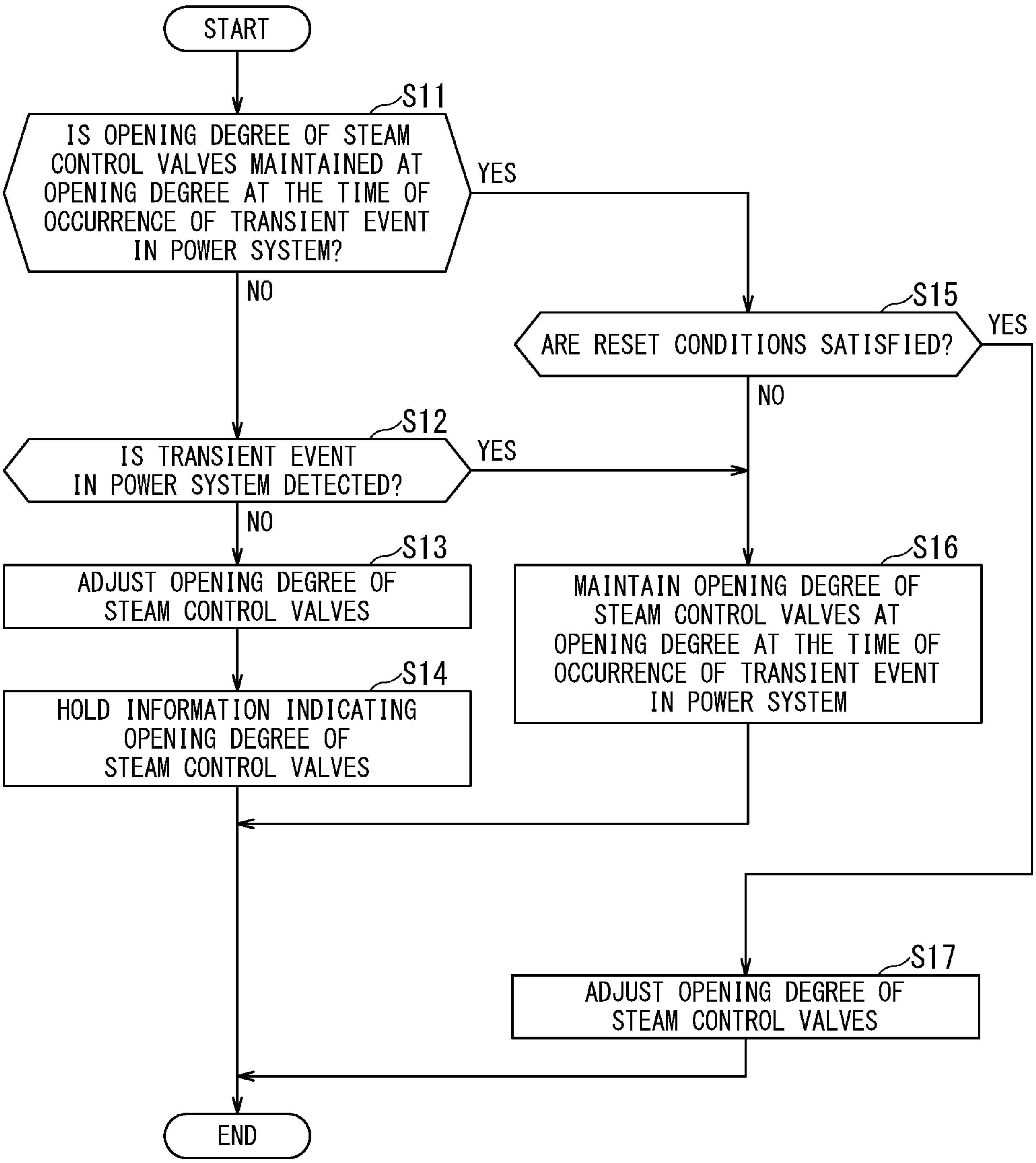
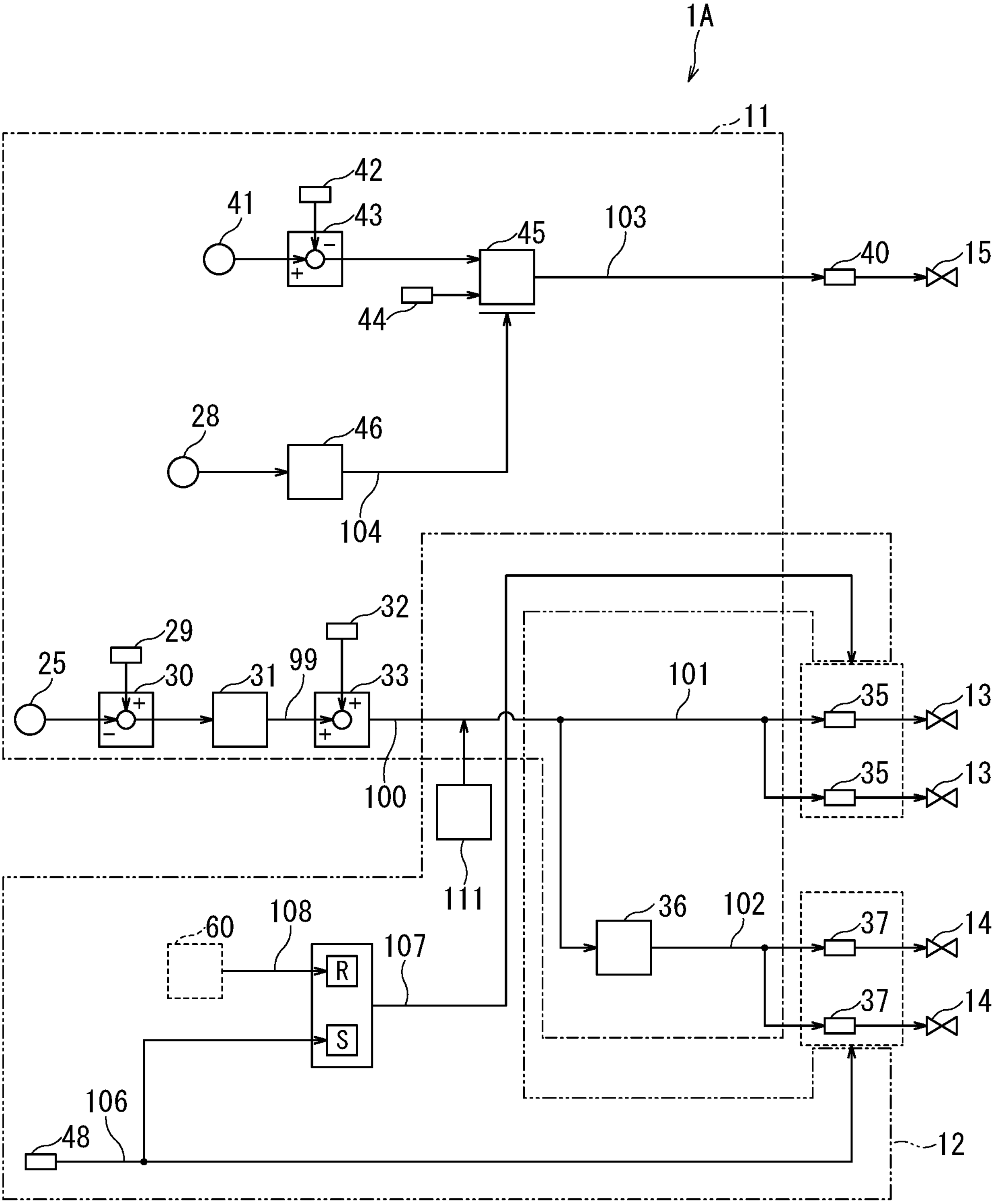

START
S11
IS OPENING DEGREE OF STEAM CONTROL VALVES MAINTAINED AT OPENING DEGREE AT THE TIME OF OCCURRENCE OF TRANSIENT EVENT IN POWER SYSTEM?
YES
NO
S15
ARE RESET CONDITIONS SATISFIED?
YES
NO
S12
IS TRANSIENT EVENT IN POWER SYSTEM DETECTED?
YES
NO
S13
ADJUST OPENING DEGREE OF STEAM CONTROL VALVES
S16
MAINTAIN OPENING DEGREE OF STEAM CONTROL VALVES AT OPENING DEGREE AT THE TIME OF OCCURRENCE OF TRANSIENT EVENT IN POWER SYSTEM
S14
HOLD INFORMATION INDICATING OPENING DEGREE OF STEAM CONTROL VALVES
S17
ADJUST OPENING DEGREE OF STEAM CONTROL VALVES
END

FIG. 4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14
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S
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48
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FIG. 5

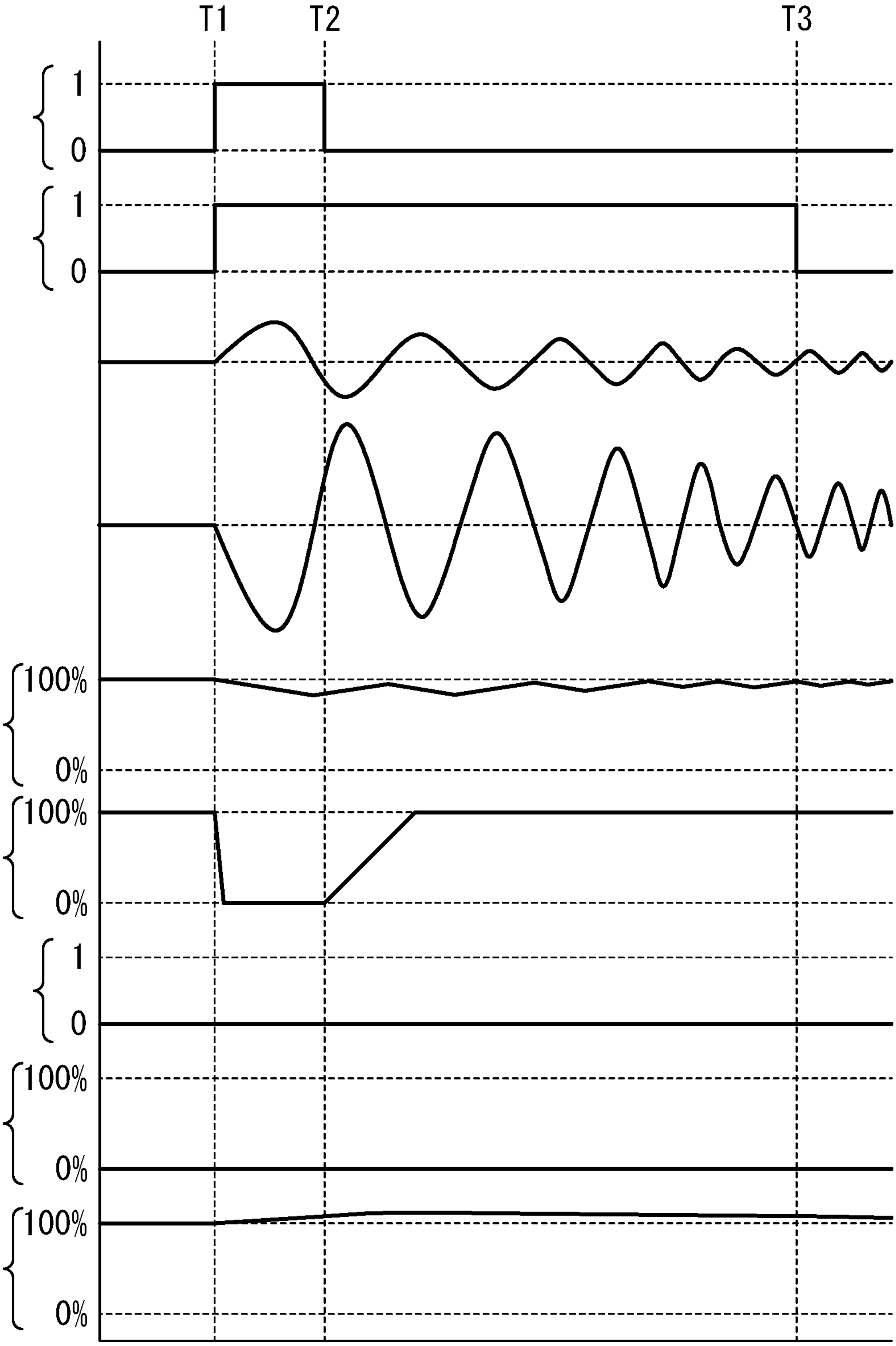


FIG. 6A

FIG. 6B

FIG. 6C

FIG. 6D

FIG. 6E

FIG. 6F

FIG. 6G

FIG. 6H

FIG. 6I

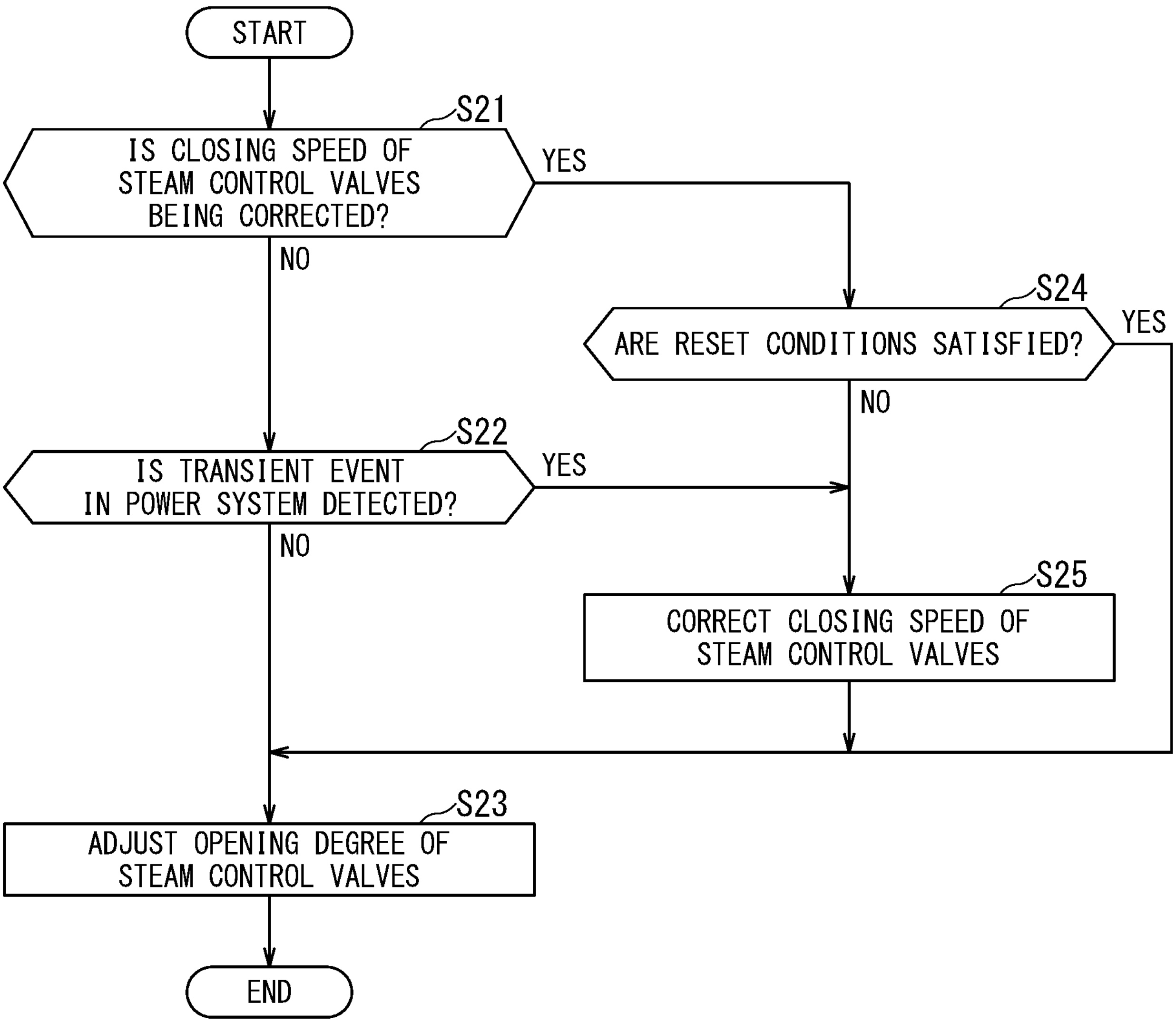
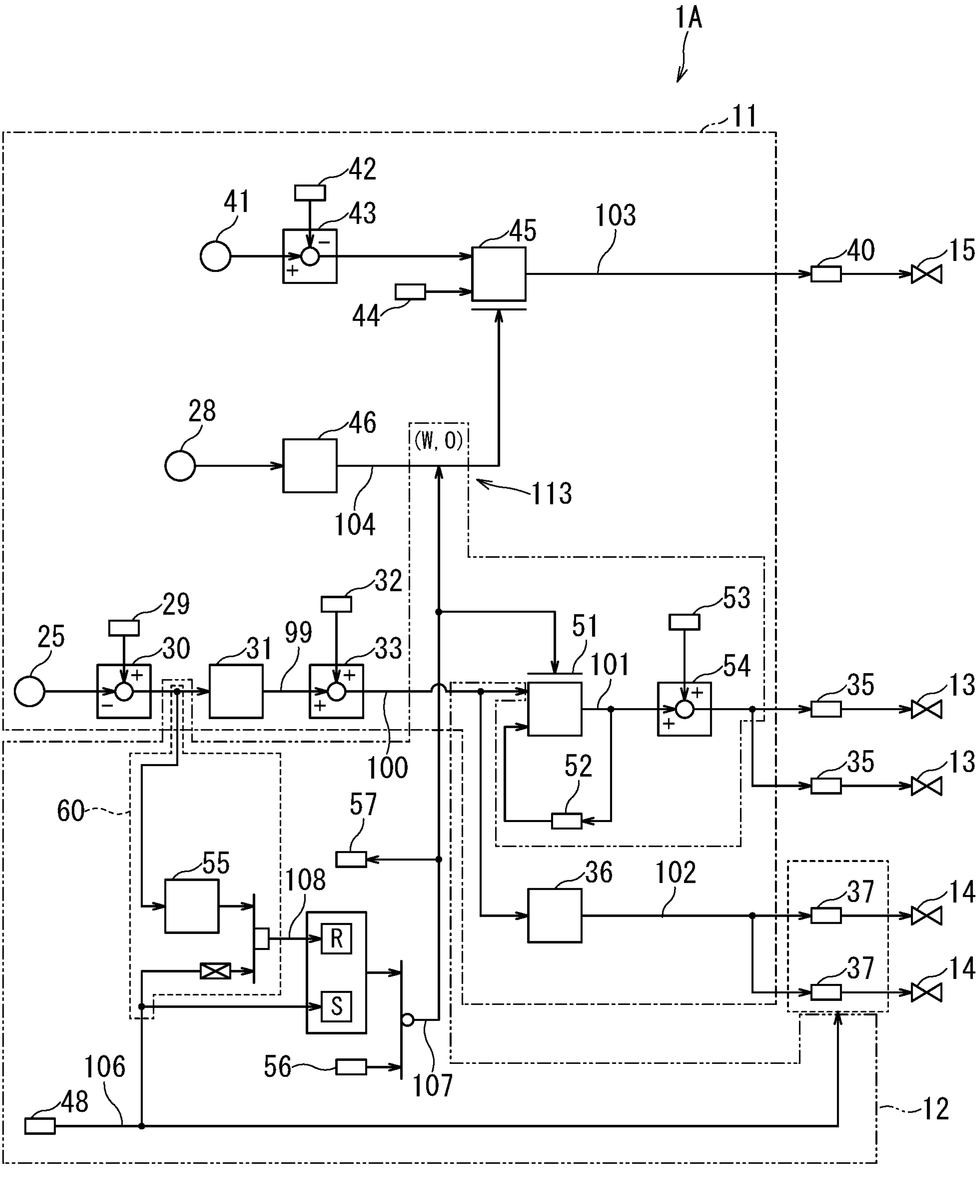

START
S21
IS CLOSING SPEED OF STEAM CONTROL VALVES BEING CORRECTED?
YES
NO
S24
ARE RESET CONDITIONS SATISFIED?
YES
NO
S22
IS TRANSIENT EVENT IN POWER SYSTEM DETECTED?
YES
NO
S25
CORRECT CLOSING SPEED OF STEAM CONTROL VALVES
S23
ADJUST OPENING DEGREE OF STEAM CONTROL VALVES
END

FIG. 7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(W, O)
113
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51
101
53
54
35
13
35
13
100
52
60
57
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36
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108
R
S
37
14
106
56
107
48
12

FIG. 8

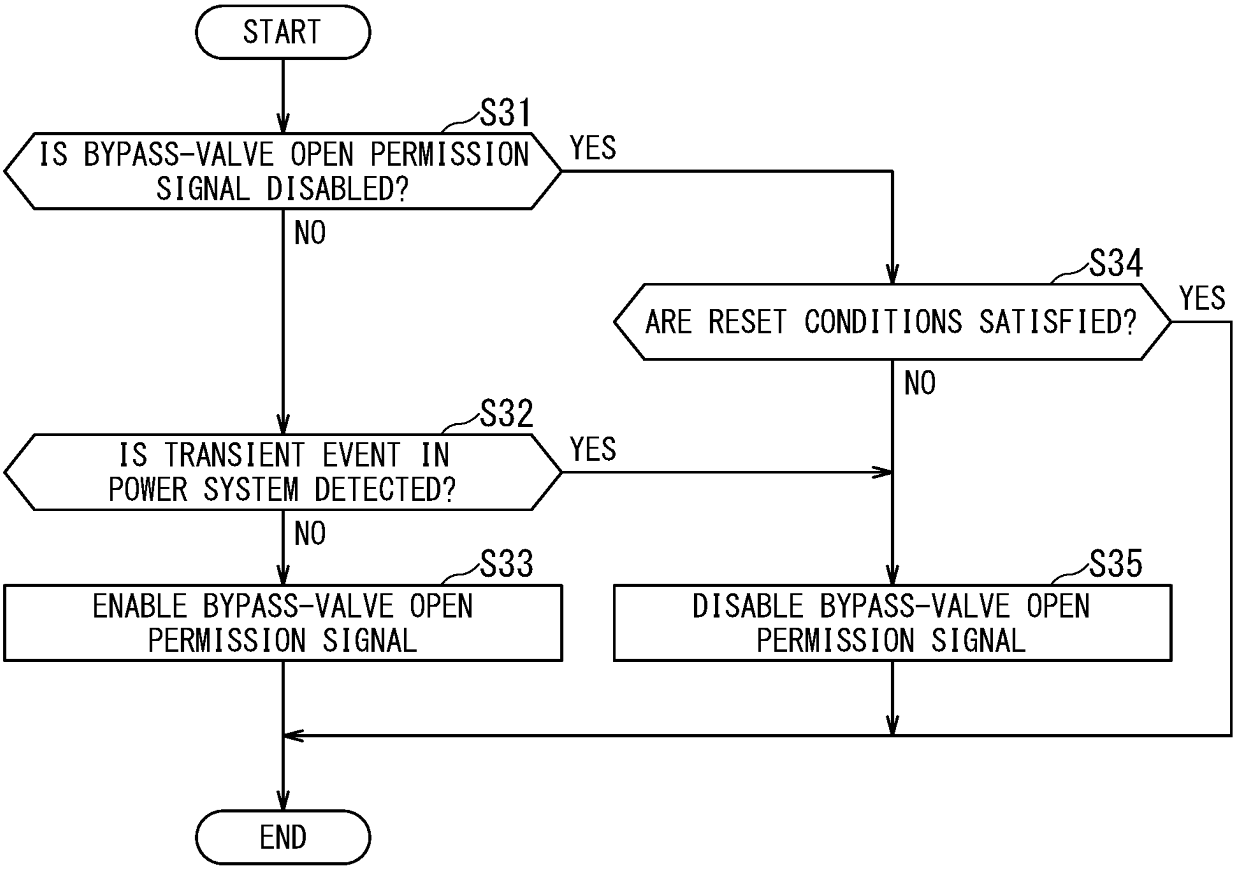
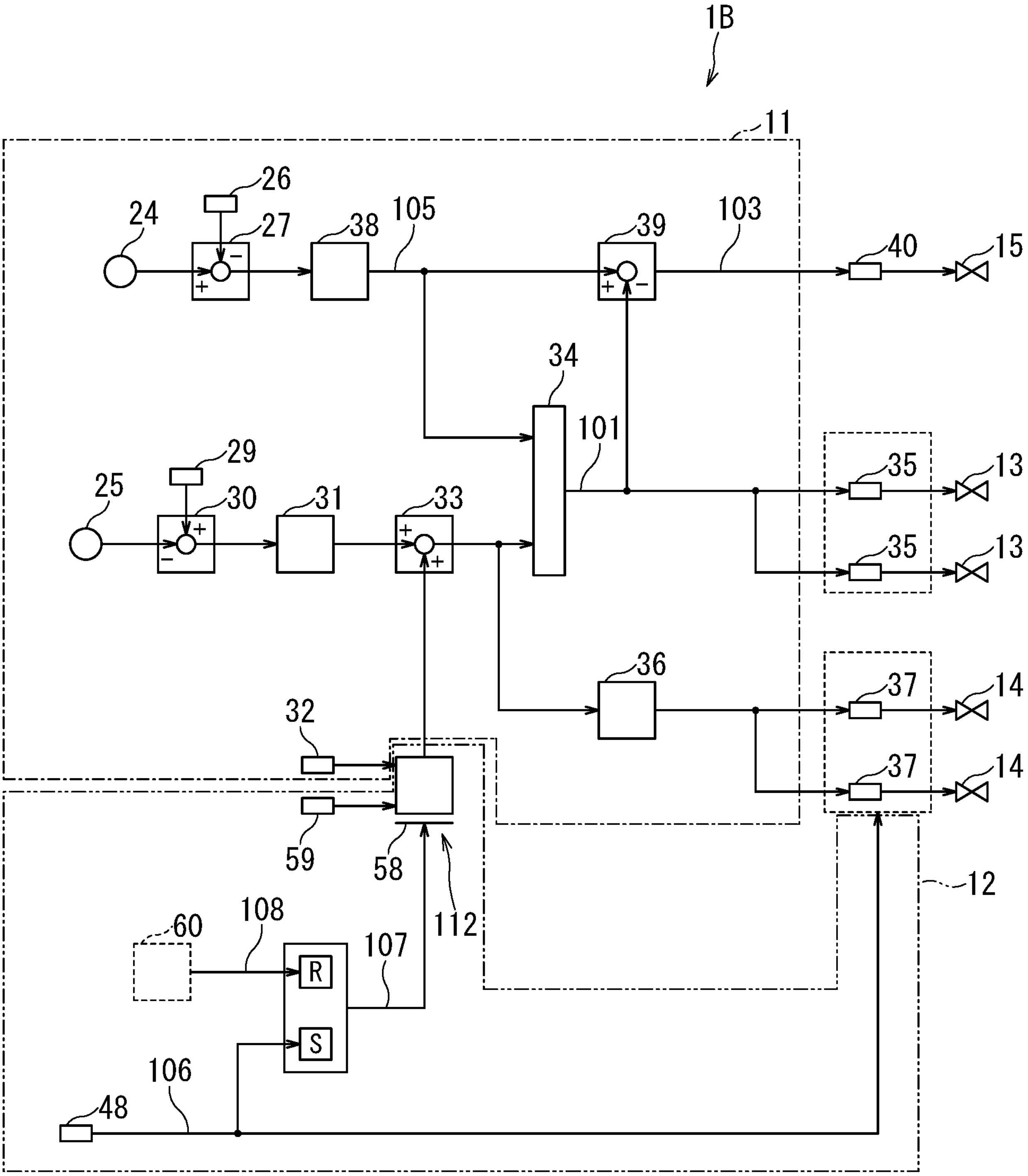

START
S31
IS BYPASS-VALVE OPEN PERMISSION SIGNAL DISABLED?
YES
NO
S34
ARE RESET CONDITIONS SATISFIED?
YES
NO
S32
IS TRANSIENT EVENT IN POWER SYSTEM DETECTED?
YES
NO
S33
ENABLE BYPASS-VALVE OPEN PERMISSION SIGNAL
S35
DISABLE BYPASS-VALVE OPEN PERMISSION SIGNAL
END

FIG. 9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13
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13
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37
14
32
59
58
112
12
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108
R
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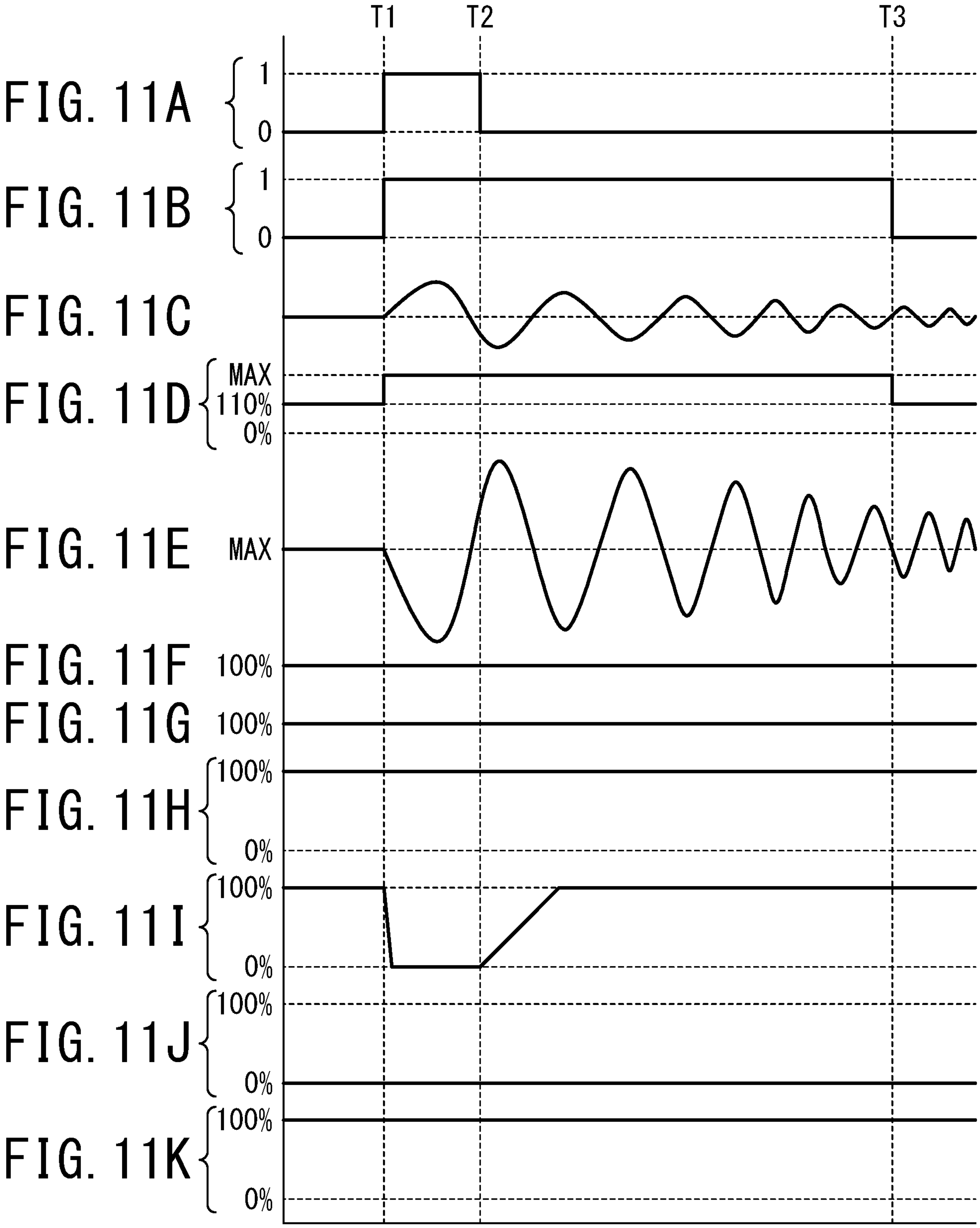
S
106
48

FIG. 10


T1
T2
T3
FIG. 11A
1
0
FIG. 11B
1
0
FIG. 11C
FIG. 11D
MAX
110%
0%
FIG. 11E
MAX
FIG. 11F
100%
FIG. 11G
100%
FIG. 11H
100%
0%
FIG. 11I
100%
0%
FIG. 11J
100%
0%
FIG. 11K
100%
0%

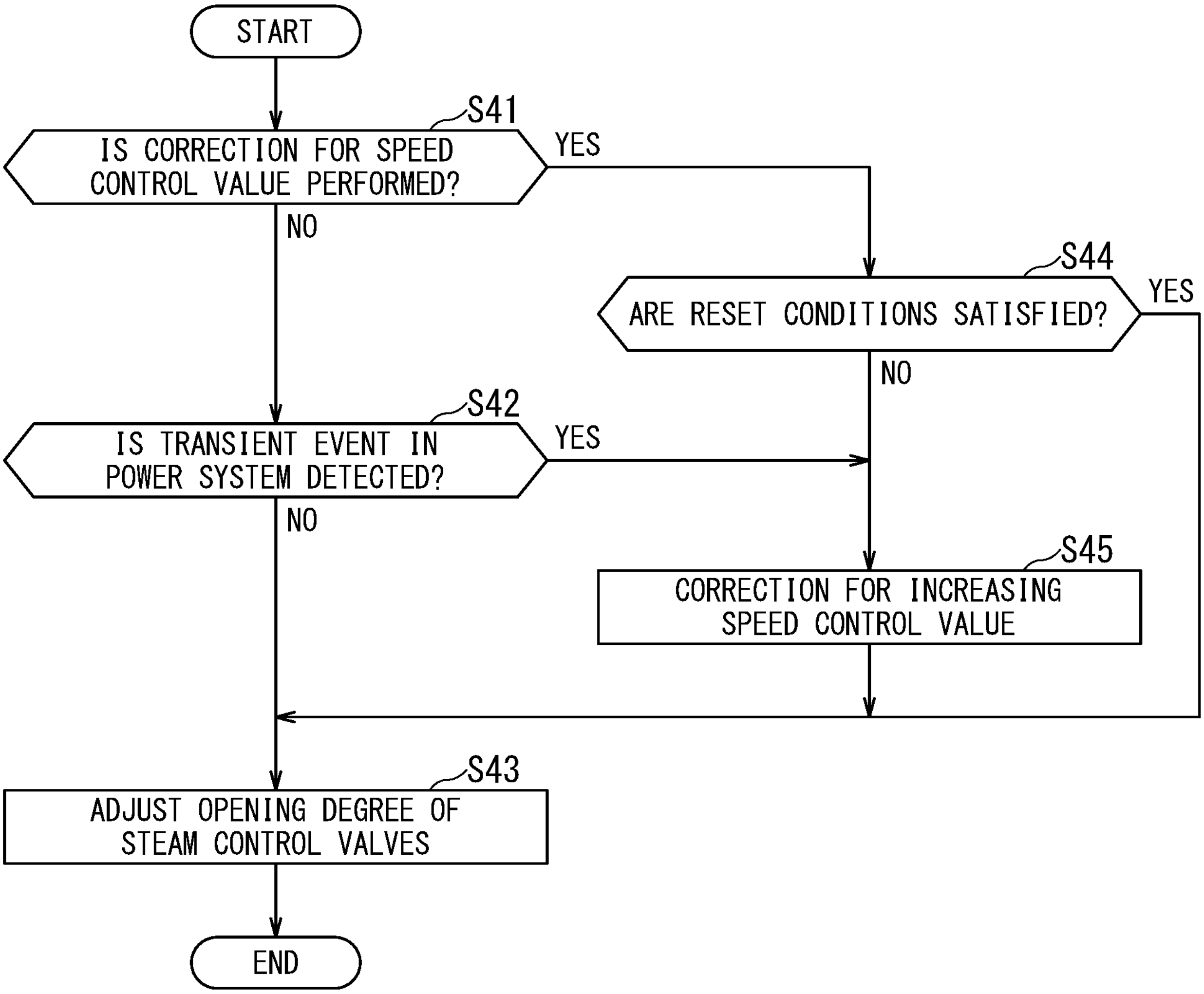

START
S41
IS CORRECTION FOR SPEED CONTROL VALUE PERFORMED?
YES
NO
S44
ARE RESET CONDITIONS SATISFIED?
YES
NO
S42
IS TRANSIENT EVENT IN POWER SYSTEM DETECTED?
YES
NO
S45
CORRECTION FOR INCREASING SPEED CONTROL VALUE
S43
ADJUST OPENING DEGREE OF STEAM CONTROL VALVES
END

FIG. 12

FIG. 13A

FIG. 13B

FIG. 13C

FIG. 13D

FIG. 13E

FIG. 13F

FIG. 13G

FIG. 13H

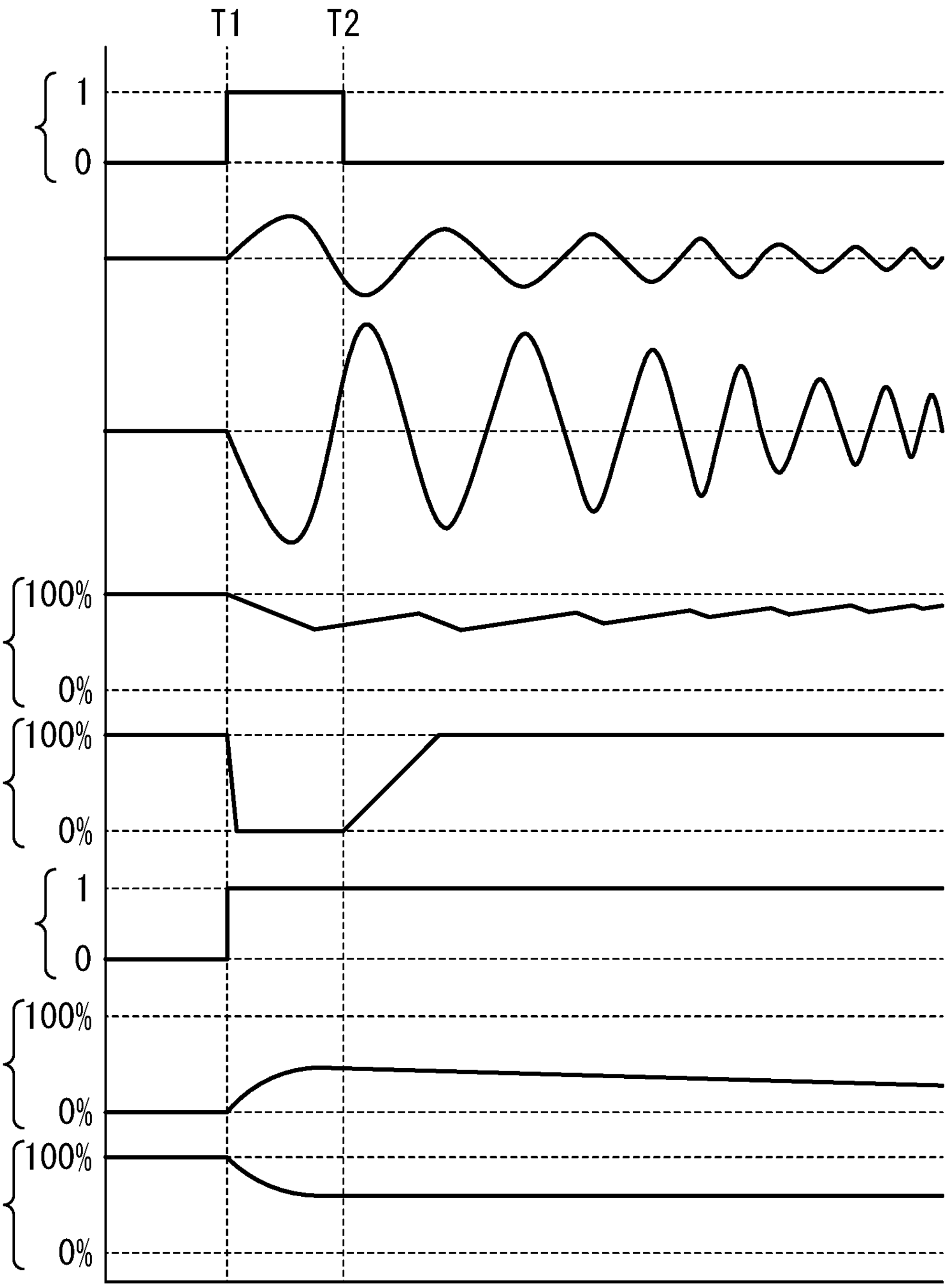
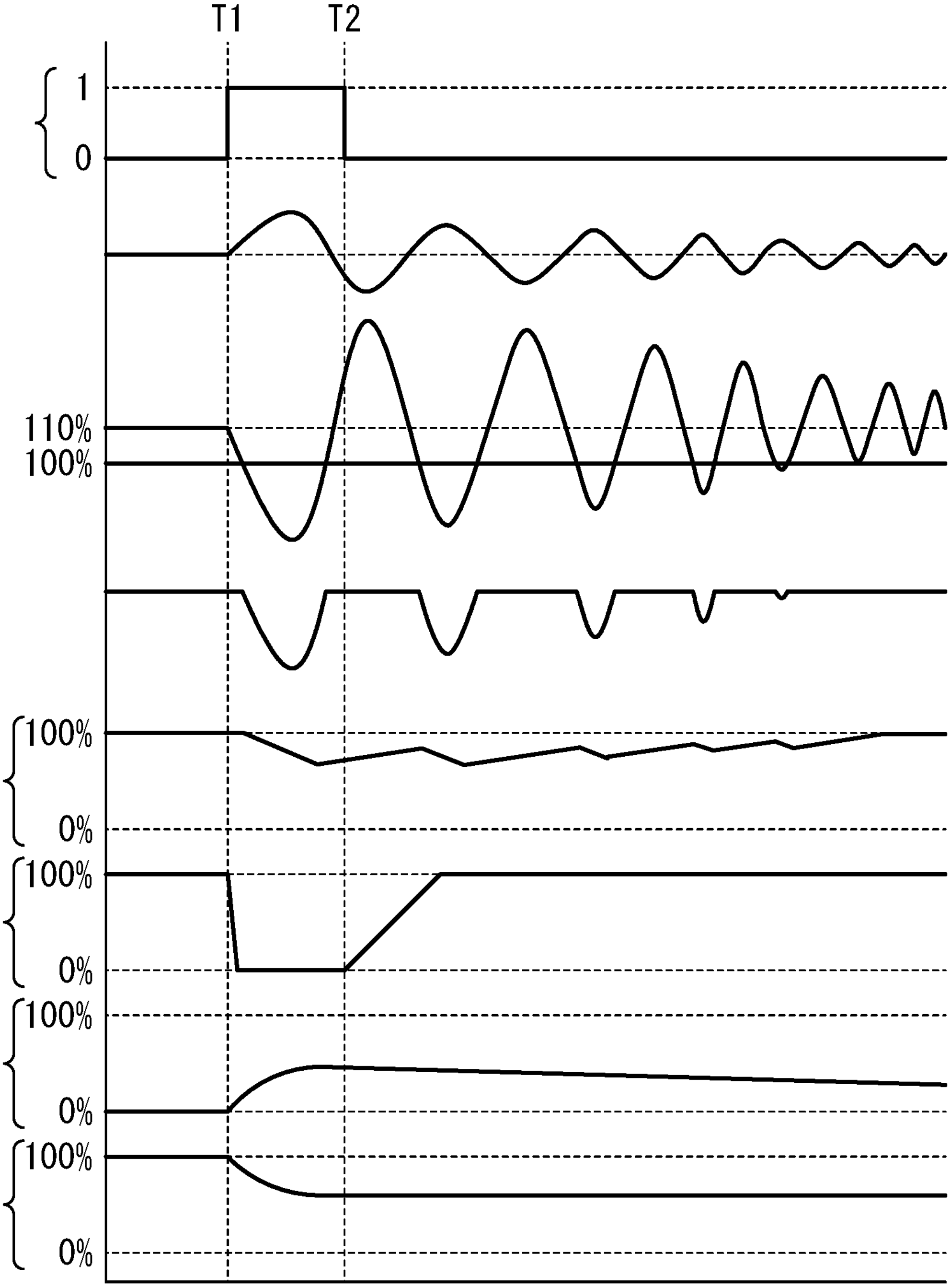


FIG. 14A
FIG. 14B
FIG. 14C
FIG. 14D
FIG. 14E
FIG. 14F
FIG. 14G
FIG. 14H
FIG. 14I



INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2019/002913

A. CLASSIFICATION OF SUBJECT MATTER
Int. Cl. F01D21/00(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
Int. Cl. F01D21/00

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Published examined utility model applications of Japan 1922-1996
Published unexamined utility model applications of Japan 1971-2019
Registered utility model specifications of Japan 1996-2019
Published registered utility model applications of Japan 1994-2019

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y A	JP 50-34727 B1 (TOKYO SHIBAURA ELECTRIC CO., LTD.) 11 November 1975, column 1, line 21 to column 5, line 1, fig. 1-6 (Family: none)	1-2, 8-9, 12 10 3-7, 11
X Y A	JP 2006-112402 A (TOSHIBA CORP.) 27 April 2006, paragraphs [0031]-[0051], fig. 1-4 (Family: none)	1, 5, 7-9, 11-12 10 2-4, 6
Y A	JP 8-165906 A (FUJI ELECTRIC CO., LTD.) 25 June 1996, paragraph [0013] (Family: none)	10 1-9, 11-12

☒ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

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"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
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Date of the actual completion of the international search	Date of mailing of the international search report
05.04.2019	16.04.2019

Name and mailing address of the ISA/	Authorized officer
Japan Patent Office 3-4-3, Kasumigaseki, Chiyoda-ku, Tokyo 100-8915, Japan	Telephone No.

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2019/002913

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y A	Microfilm of the specification and drawings annexed to the request of Japanese Utility Model Application No. 163678/1975 (Laid-open No. 074901/1977) (MITSUBISHI ELECTRIC CORP.) 04 June 1977, page 3, lines 10-14 (Family: none)	10 1-9, 11-12
A	JP 2017-57837 A (TOSHIBA CORP.) 23 March 2017 (Family: none)	1-12

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REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP S62210204 A **[0003]**
- JP 2014159744 A **[0003]**