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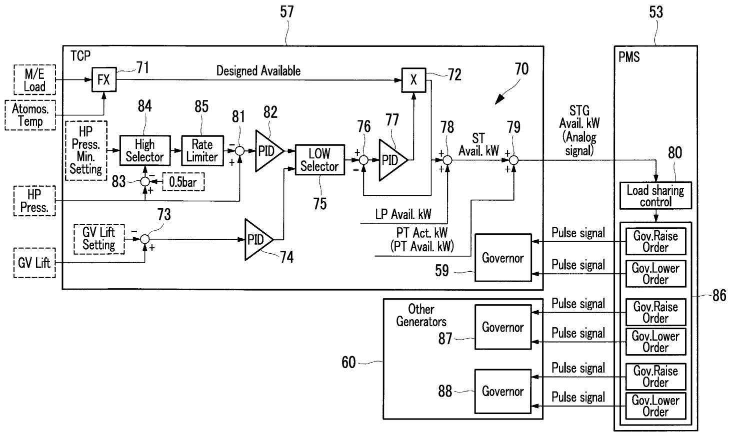
(54) **CONTROL DEVICE FOR POWER GENERATION SYSTEM, POWER GENERATION SYSTEM, AND POWER GENERATION METHOD**

(57) In the present invention, a turbine control panel (TCP) (57) performs a pressure-changing operation wherein the pressure of steam introduced into a steam turbine is changed. In addition, a load capacity value calculation unit (70) with which the TCP (57) is provided calculates the actual load capacity value obtained from the steam turbine on the basis of the deviation between a target degree of opening of a speed adjustment valve and the actual degree of opening of the speed adjustment valve, and controls the degree of opening of the speed adjustment valve on the basis of the calculated load capacity value. Thus, the TCP (57) does not use a pulse signal, as in the prior art, to change the load capacity value used in controlling the degree of opening of the speed adjustment valve, so the speed adjustment valve can be controlled without the occurrence of a time lag that is typical of a pulse signal.

FIG. 3



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Description

Technical Field

[0001] The present invention relates to a control device for a power generation system, a power generation system, and a power generation method.

Background Art

[0002] As an exhaust heat recovery for a ship (hereinafter, referred to as "marine exhaust heat recovery"), a power generation system in which a part of exhaust gas of a diesel engine (main engine) for ship propulsion is extracted and is guided to a power turbine to be used as a power generation output and steam generated using the exhaust gas of the diesel engine is guided to a steam turbine to be used as a power generation output is known. In such a power generation system, a governor is provided in the steam turbine to adjust the flow rate of fluid for driving the steam turbine.

[0003] PTL 1 discloses a technique in which a governor is provided in a steam turbine and a control signal generated by the governor is output to an adjusting valve to change an output of the steam turbine.

Citation List

Patent Literature

[0004] [PTL 1] Japanese Patent No. 5155977

Summary of Invention

Technical Problem

[0005] In the above-mentioned marine exhaust heat recovery, as an example of a technique for causing generated steam to flow into a steam turbine to the maximum to be recovered as an output of a generator, there is a pressure-changing operation for operating a governor valve that controls the flow rate of steam that is introduced to the steam turbine at a position where the governor valve is fully opened as much as possible. In the exhaust heat recovery according to such a pressure-changing operation, since a steam pressure is changed according to the amount of exhaust heat from a main engine, a maximum output capable of being generated by the steam turbine is also changed.

[0006] Here, load sharing with another generator (a diesel engine generator) that configures a power generation system will be described with reference to a different point from power generation in an overland plant.

[0007] In power generation in an overland plant that is interconnected to a commercial power supply system and is capable of being connected in parallel to an infinite bus, the frequency of generated power is determined by a system frequency of the infinite bus. Thus, in the overland plant that is interconnected to the commercial power supply system, the opening degree of a governor valve is fixed in the vicinity of a fully opened position or a fully opened position, and the generated power can be consequently output.

[0008] On the other hand, since a power generation system for a ship is a so-called microgrid (also referred to as an island mode), which is not connected to an infinite bus, a governor of a generator cannot fix an opening degree of a governor valve and is operated by a governor control. Further, a power management system (PMS) monitors the frequency of generated power and controls load sharing using an available power (an output capable of being used by a generator) of each generator so that the frequency becomes a predetermined value. In addition, in the marine exhaust heat recovery based on the pressure-changing operation, since an available power of a generator cannot be fixed to a constant value, the following method is used for control of generated power.

[0009] Here, in the pressure-changing operation of the marine exhaust heat recovery, the pressure of main steam is also changed in addition to change of the amount of exhaust heat, but it is difficult to accurately calculate an available power of each generator according to changes through measurement and calculation.

[0010] Thus, in the related art, as shown in Fig. 9, a PMS 100 retains (stores) in advance an available power value by an available power valve retaining unit 102, and increases or decreases the available power value retained in the available power value retaining unit 102 by a pulse signal (on/off signal) output from a turbine control panel (TCP) 104. The pulse signal output from the TCP 104 is based on the pressure of main steam and the opening degree of the governor valve, and is a value for increasing (increment) or decreasing (decrement) the available power value in stages by a predetermined value. In this way, the reason why the control for increasing or decreasing the retained available power value in stages by the pulse signal is that it is difficult to accurately calculate an absolute value of the available power value in the pressure-changing operation.

[0011] Further, a governor control in the related art in the pressure-changing operation will be described in detail with reference to Fig. 9.

[0012] The PMS 100 includes a load sharing control unit 106 and a governor increase/decrease pulse generator 108. The load sharing control unit 106 generates a load sharing signal indicating load sharing of a steam turbine and another generator 110 (diesel engine generator) on the basis of the available power value retained in the available power value retaining unit 102. The governor increase/decrease pulse generator 108 generates a governor increase/decrease pulse signal for increasing or decreasing a control value (speed setting) with respect to the steam turbine and the other generator 110 on the basis of the load sharing signal from the load sharing control unit 106, and outputs the result to governors 112A, 112B, and 112C.

[0013] The governor 112A is provided in the TCP 104, and controls a rotation speed of the steam turbine. The governor 112A outputs an opening degree of a governor valve based on the speed setting (governor increase/decrease pulse signal) of the rotation speed instructed by the PMS 100 to the governor 112A, to thereby control an output of the steam turbine and perform a control so that the opening degree of the governor valve becomes a target opening degree.

[0014] The governors 112B and 112C are respectively provided in the generator 110, and control a rotation speed of the generator 110. The governors 112B and 112C output the opening degree of the governor valve based on the speed setting (governor increase/decrease pulse signal) of the rotation speed instructed by the PMS 100 to the governor valve, to thereby control an output of the generator 110.

[0015] On the other hand, in order to output the pulse signal to the PMS 100, for example, the TCP 104 includes a comparator 114, a comparator 116, an increase pulse output unit 118, and a decrease pulse output unit 120. The comparator 114 compares an actual opening degree of the governor valve of the steam turbine with a target opening degree thereof. The comparator 116 compares a measurement value of the pressure of main steam with a set value of a minimum pressure of the pressure of the main steam. Further, the increase pulse output unit 118 generates an increase pulse signal for increasing an available power value on the basis of the comparison results of the comparators 114 and 116. Further, the decrease pulse output unit 120 generates a decrease pulse signal for decreasing the available power value on the basis of the comparison results of the comparators 114 and 116.

[0016] That is, as the results of comparison based on the comparators 114 and 116, in a case where the opening degree of the governor valve does not satisfy the target opening degree, the increase pulse signal is output to the PMS 100 from the increase pulse output unit 118. Further, as the results of comparison based on the comparators 114 and 116, in a case where the opening degree of the governor valve exceeds the target opening degree, or in a case where the pressure of the main steam is smaller than the minimum pressure, the decrease pulse signal is output to the PMS 100 from the decrease pulse output unit 120.

[0017] If a pulse signal is input from the TCP 104, the PMS 100 increases or decreases the available power value retained in the available power value retaining unit 102 according to the pulse signal. The PMS 100 determines load sharing of the steam turbine and the other generator 110 by the load sharing control unit 106 on the basis of the increased or decreased available power value, and outputs the governor increase/decrease pulse signal to the governors 112A, 112B, and 112C. Further, as described above, when the governor 112A controls the opening degree of the governor valve, in a case where the opening degree of the governor valve after the control is different from the target opening degree, for example, the increase pulse signal or the decrease pulse signal is output to the PMS 100 from the TCP 104, and the available power value is increased or decreased in stages by a predetermined value.

[0018] Here, since if the amount of exhaust heat or the like is also changed as a condition of a plant are changed in marine exhaust heat recovery, an actual available power is also changed, it is also necessary to change the available power value retained in the PMS 100 as described above.

[0019] However, since the available power value is increased or decreased by the pulse signal from the TCP 104, the speed of the change of the available power value depends on the interval (hereinafter, referred to as a "pulse interval") or the width (hereinafter, referred to as a "pulse width") of the pulse signal. Further, there is a case in which the PMS 100 performs weighting with respect to the pulse signal from the TCP 104 to change the available power value. In such a case, the speed of the change of the available power value also depends on the weighting. The weighting is performed on the basis of the opening degree of the governor valve, the pressure of the main steam, the output of the steam turbine generator (hereinafter, referred to as an "STG output"), a main engine load, or the like.

[0020] The pulse interval or the pulse width of the pulse signal output from the TCP 104, the weighting with respect to the pulse signal in the PMS 100, and the like are factors that affect a response of the STG output and also are adjusting items for adjusting the response in a case where a condition of a plant such as the amount of exhaust heat is changed. Further, in a case where the response of the STG output cannot be appropriately controlled, there is a possibility that hunting or the like occurs.

[0021] However, in the increase or decrease of the available power value based on the pulse signal, a delay occurs due to increase or decrease in stages, for example. Thus, although a condition of a plant is changed, an optimal value of the condition of the plant cannot be reflected in the available power value without a time lag, and the control of the opening degree of the governor valve is also delayed. Accordingly, although the pulse interval or pulse width of the pulse signal output from the TCP 104, the weighting with respect to the pulse signal in the PMS 100, and the like are adjusted, there is a case in which it is not possible to prevent hunting.

[0022] Further, in a plant in which a power turbine is connected to an STG, as described above, only with the increase or decrease of the available power value using the pulse signal to maintain the pressure of main steam or the opening degree of the governor valve at a target value, although the output of the power turbine is changed, the available power value is not changed.

[0023] Here, a related-art control using a pulse signal in a configuration in which a governor is not provided in a power turbine will be described.

[0024] In the related-art control using the pulse signal, in a case where an output of the power turbine is changed as a condition of a plant is changed, the frequency is also changed. Thus, the governor 112A is operated to absorb the change of the output of the power turbine according to a speed droop characteristic, and accordingly, the governor 112A changes an opening degree of a governor valve. Thereafter, the PMS 100 increases or decreases the available power value according to a pulse signal to maintain the pressure of main steam or the opening degree of the governor valve at a target value.

[0025] In this way, in the related-art control using the pulse signal, the governor valve of the steam turbine is controlled every time according to the change of the output of the power turbine and the change of the available power value. Thus, while the condition of the plant is being changed, the opening degree of the governor valve is excessively decreased or is fixed at a fully opened position, and thus, there is a possibility that the control becomes unstable.

[0026] As described above, in the marine exhaust heat recovery in the related art, since the available power value is increased or decreased by a pulse signal, there is a possibility that if a condition of a plant is changed, the control becomes unstable.

[0027] The invention has been made in consideration of the above-mentioned problems, and an object of the invention is to provide a control device for a power generation system, a power generation system, and a power generation method capable of performing stable control in exhaust heat recovery in a case where a condition of a plant is changed.

Solution to Problem

[0028] In order to solve the above problems, a control device for a power generation system, a power generation system, and a power generation method employ the following means.

[0029] According to a first aspect of the invention, there is provided a control device for a power generation system that includes a steam turbine that is driven by steam generated by exhaust gas, a governor valve that controls the flow rate of steam that is introduced to the steam turbine, and a generator that is connected to the steam turbine, and performs a pressure-changing operation for changing the pressure of the steam that is introduced to the steam turbine, the control device for a power generation system including: calculation means for calculating an actual available power value obtained from the steam turbine on the basis of a difference between a target opening degree of the governor valve and an actual opening degree of the governor valve; and control means for controlling an opening degree of the governor valve on the basis of the available power value calculated by the calculation means.

[0030] The power generation system according to this configuration includes the steam turbine that is driven by the steam generated by exhaust gas, the governor valve that controls the flow rate of steam that is introduced to the steam turbine, and the generator that is connected to the steam turbine, and performs exhaust heat recovery in which exhaust heat is used for power generation. The exhaust gas is generated by a main engine, for example. Further, the power generation system according to this configuration performs a control so that the opening degree of the governor valve becomes constant (the target opening degree), to thereby perform a pressure-changing operation for changing the pressure of steam that is introduced to the steam turbine.

[0031] Here, in the related-art control, for example, an available power value indicating an output of a steam turbine capable of being used by a generator is retained in advance in a PMS, and the retained available power value is increased or decreased in stages by a predetermined value by a pulse signal output from a TCP. Further, control means controls a governor valve of the steam turbine on the basis of the retained available power value, so that the output of the steam turbine is controlled and the opening degree of the governor valve is controlled to become a target opening degree.

[0032] However, since the increase or decrease of the available power value due to the pulse signal causes a time lag, although a condition of a plant is changed, an optimal value of the condition of the plant cannot be reflected in the available power value without a delay at that time, and a delay occurs even in the control of the opening degree of the governor valve.

[0033] Thus, in this configuration, the calculation means calculates the actual available power value obtained from the steam turbine on the basis of the difference between the target opening degree of the governor valve and the actual opening degree of the governor valve as an absolute value. The available power value calculated by the calculation means is not a pulse signal as in the related art, but is an analog signal (voltage value). Further, the opening degree of the governor valve is controlled by the control means on the basis of the calculated available power value, and the opening degree of the governor valve comes close to the target opening degree.

[0034] In this way, in this configuration, the actual available power value is not calculated by various measurement values, and the available power value is calculated on the basis of the difference between the actual opening degree of the governor valve and the target opening degree, and the opening degree of the governor valve is controlled. That is, in this configuration, the actual opening degree of the governor valve is compared with the target opening degree, and the available power value is increased or decreased so that the opening degree of the governor valve becomes the target opening degree. Thus, in this configuration, since the available power value used for the control of the opening degree of the governor valve is not increased or decreased by the pulse signal as in the related art, it is possible to control the governor valve without a time lag specific to such a pulse signal.

[0035] Accordingly, in this configuration, it is possible to perform more stable control in exhaust heat recovery in a case where a condition of a plant is changed.

[0036] In the above-described first aspect, an upper limit may be determined with respect to the available power value calculated by the calculation means.

[0037] According to this configuration, the upper limit of the available power value is a value calculated on the basis of a load of the main engine and an outside air temperature, for example. Since the upper limit is set with respect to the available power value, the available power value based on the reality is calculated.

[0038] In the above-described first aspect, the calculation means may calculate a smaller value among a first available power value based on the difference between the target opening degree of the governor valve and the actual opening degree of the governor valve and a second available power value based on a difference between a set value of the pressure of the steam that is introduced to the steam turbine and an actual pressure of the steam, as an actual available power value obtained from the steam turbine.

[0039] As the opening degree of the governor valve increases, the pressure of steam decreases, but since a minimum value is set in the pressure of steam, it is necessary to set the actual pressure of steam so as not to be smaller than the set minimum value. Here, a case in which the second available power value is smaller than the first available power value refers to a case where the actual pressure of steam is smaller than the set minimum value. In such a case, the second available power value is selected, and an available power value capable of maintaining the actual pressure of steam to be equal to or greater than the minimum value is selected.

[0040] Thus, it is possible to prevent the pressure of steam that is introduced to the steam turbine from being smaller than the set minimum value.

[0041] In the above-described first aspect, the control device for a power generation system may further include a power turbine that is driven by the exhaust gas, the generator may be connected to the power turbine and the steam turbine, and the calculation means may output a sum of the calculated available power value and an output value of the power turbine as an available power value capable of being used by the generator.

[0042] According to this configuration, although the generator is connected to the power turbine and the steam turbine, it is possible to calculate an available power value capable of being easily used by the generator.

[0043] In the above-described first aspect, the output value of the power turbine may be calculated by subtracting a calculation value of an output of the steam turbine from a measurement value of an output of the generator.

[0044] According to this configuration, it is possible to easily calculate an absolute value of the output value of the power turbine.

[0045] According to a second aspect of the invention, there is provided a control device for a power generation system that includes a power turbine that is driven by exhaust gas, a steam turbine that is driven by steam generated by the exhaust gas, a governor valve that controls the flow rate of steam that is introduced to the steam turbine, and a generator that is connected to the power turbine and the steam turbine, and performs a pressure-changing operation for changing the pressure of the steam that is introduced to the steam turbine, the control device for a power generation system including: calculation means for calculating an output value of the power turbine by subtracting a calculation value of an output of the steam turbine from a measurement value of an output of the generator and calculating an available power value of the generator by adding the calculated output value of the power turbine to an available power value obtained from the steam turbine; and control means for controlling an opening degree of the governor valve on the basis of the available power value of the generator calculated by the calculation means.

[0046] The power generation system according to this configuration includes the power turbine that is driven by the exhaust gas, the steam turbine that is driven by the steam generated by the exhaust gas, the governor valve that controls the flow rate of steam that is introduced to the steam turbine, and the generator that is connected to the power turbine and the steam turbine, and performs exhaust heat recovery in which exhaust heat is used in power generation. The exhaust gas is generated by a main engine, for example. Further, the power generation system according to this configuration controls the opening degree of the governor valve to be constant (target opening degree), to thereby perform a pressure-changing operation for changing the pressure of steam that is introduced to the steam turbine.

[0047] In the related-art control using a pulse signal, the governor valve of the steam turbine is controlled every time according to the change of the output of the power turbine and the change of the available power value. Thus, while a condition of a plant is being changed, the opening degree of the governor valve is excessively decreased or is fixed at a fully opened position, and thus, there is a possibility that the control becomes unstable.

[0048] On the other hand, in this configuration, the output value of the power turbine is calculated by subtracting the calculation value of the output of the steam turbine from the measurement value of the output of the generator, and the available power value of the generator is calculated by adding the calculated output value of the power turbine to the available power value obtained from the steam turbine. Thus, the change of the output of the power turbine is reflected in the available power value of the generator in real time. Accordingly, although the output of the power turbine is changed, it is possible to obtain the calculated available power value of the generator without a time lag, and thus, it is possible to stabilize the control of the governor valve.

[0049] Accordingly, in this configuration, it is possible to perform stable control in exhaust heat recovery in a case where a condition of a plant is changed.

[0050] According to a third aspect of the invention, there is provided a power generation system that includes the above-described control device and performs a pressure-changing operation for changing the pressure of steam that is introduced to the steam turbine.

[0051] According to a fourth aspect of the invention, there is provided a power generation method that includes a step of driving a steam turbine by steam generated by exhaust gas, a step of controlling the flow rate of steam that is introduced to the steam turbine using a governor valve, and a step of performing power generation by driving of the steam turbine, and performs a pressure-changing operation for changing the pressure of the steam that is introduced to the steam turbine, the power generation method including: a first step of calculating an actual available power value obtained from the steam turbine on the basis of a difference between a target opening degree of the governor valve and an actual opening degree of the governor valve; a second step of controlling an opening degree of the governor valve on the basis of the available power value calculated in the first step.

[0052] According to a fifth aspect of the invention, there is provided a power generation method that includes a step of driving a power turbine by exhaust gas, a step of driving a steam turbine by steam generated by the exhaust gas, a step of controlling the flow rate of steam that is introduced to the steam turbine, and a step of performing power generation by driving of the power turbine and the steam turbine using a governor valve, and performs a pressure-changing operation for changing the pressure of the steam that is introduced to the steam turbine, the power generation method including: a first step of calculating an output value of the power turbine by subtracting a calculation value of an output of the steam turbine from a measurement value of an output of the generator and calculating an available power value of the generator by adding the calculated output value of the power turbine to an available power value obtained from the steam turbine; and a second step of controlling an opening degree of the governor valve on the basis of the available power value of the generator calculated in the first step.

Advantageous Effects of Invention

[0053] According to the invention, in exhaust heat recovery in a case where a condition of a plant is changed, it is possible to achieve more stable control.

Brief Description of Drawings

[0054]

Fig. 1 is a schematic configuration diagram illustrating a turbine generator system according to an embodiment of the invention.

Fig. 2 is a schematic configuration diagram illustrating a power generation system according to an embodiment of the invention.

Fig. 3 is a functional block diagram relating to a governor control according to an embodiment of the invention.

Fig. 4 shows an example of a functional block diagram relating to calculation of an output value of a power turbine in an available power value calculation unit according to an embodiment of the invention.

Fig. 5 is a graph illustrating temporal changes of various control values in a pressure-changing operation according to an embodiment of the invention.

Fig. 6A is a graph illustrating temporal changes of various control values in the related art when a power turbine is operated.

Fig. 6B is a graph illustrating temporal changes of various control values according to an embodiment of the invention when a power turbine is operated.

Fig. 7A is a graph illustrating temporal changes of various control values in the related art when a power turbine is stopped.

Fig. 7B is a graph illustrating temporal changes of various control values according to an embodiment of the invention when a power turbine is stopped.

Fig. 8A is a graph illustrating temporal changes of various control values in the related art when an inboard power load increases.

Fig. 8B is a graph illustrating temporal changes of various control values according to an embodiment of the invention when an inboard power load increases.

Fig. 9 is a block diagram according to a governor control in the related art.

Description of Embodiments

[0055] Hereinafter, embodiments of a control device for a power generation system, a power generation system, and a power generation method according to the invention will be described with reference to the accompanying drawings.

[0056] Fig. 1 shows a schematic configuration of a turbine generator system 1 of a power generation system according to an embodiment of the invention. In this embodiment, a diesel engine for ship propulsion is used as a main engine 3.

[0057] The turbine generator system 1 includes the main engine 3, a turbocharger 5 that is driven by exhaust gas of the main engine 3, a power turbine (gas turbine) 7 that is driven by the exhaust gas of the main engine 3 extracted from an upstream side of the turbocharger 5, an exhaust gas economizer 11 that generates steam by using the exhaust gas of the main engine 3, and a steam turbine 9 that is driven by the steam (high-pressure steam) generated by the exhaust gas economizer 11.

[0058] An output from the main engine 3 is directly or indirectly connected to a screw propeller through a propeller shaft. Further, an exhaust port of a cylinder portion 13 of each cylinder of the main engine 3 is connected to an exhaust manifold 15 which is an exhaust gas collecting pipe. The exhaust manifold 15 is connected to an inlet side of a turbine portion 5a of the turbocharger 5 through a first exhaust gas pipe L1. Further, the exhaust manifold 15 is connected to an inlet side of the power turbine 7 through a second exhaust gas pipe L2 (steam extracting passage). A part of the exhaust gas is extracted before being supplied to the turbocharger 5 to then be supplied to the power turbine 7.

[0059] On the other hand, a gas supply port of each cylinder portion 13 is connected to a gas supply manifold 17, and the gas supply manifold 17 is connected to a compressor portion 5b of the turbocharger 5 through a gas supply pipe K1. Further, an air cooler (intercooler) 19 is provided in the gas supply pipe K1.

[0060] The turbocharger 5 includes the turbine portion 5a, the compressor portion 5b, and a rotation shaft 5c that connects the turbine portion 5a and the compressor portion 5b.

[0061] The power turbine 7 is rotationally driven by exhaust gas extracted from the exhaust manifold 15 through the second exhaust gas pipe L2, and the steam turbine 9 is supplied with steam generated by the exhaust gas economizer 11 to be rotationally driven.

[0062] The exhaust gas economizer 11 is supplied with exhaust gas discharged from an output port of the turbine portion 5a of the turbocharger 5 through a third exhaust gas pipe L3 and exhaust gas discharged from an output port of the power turbine 7 through a fourth exhaust gas pipe L4, and evaporates water supplied through a water supply pipe 23 using heat of the exhaust gas to generate steam by a heat exchanger 21. Further, the steam generated by the exhaust gas economizer 11 is introduced to the steam turbine 9 through a first steam pipe J1, and the steam after processing in the steam turbine 9 is discharged through a second steam pipe J2 and is guided to a condenser (steam condenser) 40.

[0063] Further, on the first steam pipe J1, a steam dump pipe J3 that extracts steam that is directed to the steam turbine 9 and guides the steam to the steam condenser 40 is provided. On the steam dump pipe J3, a dump valve 41 that controls the flow rate of the steam that is guided from the steam dump pipe J3 to the steam condenser 40 is provided. Steam to be excessive in being supplied to the steam turbine 9 passes by the steam turbine 9 to be discarded to the steam condenser 40 by the steam dump pipe J3.

[0064] The power turbine 7 and the steam turbine 9 are coupled in series to drive a turbine generator 25. A rotation shaft 29 of the steam turbine 9 is connected to the turbine generator 25 through a speed reducer and a coupling (which are not shown), and a rotation shaft 27 of the power turbine 7 is connected to the rotation shaft 29 of the steam turbine 9 through a speed reducer (not shown) and a clutch 31. A clutch detachably mounted with a predetermined number of revolutions is used as the clutch 31, and a synchro self shifting (SSS) clutch is preferably used, for example. In this embodiment, the power turbine 7 and the steam turbine 9 are coupled in series to drive the turbine generator 25, but the power turbine 7 and the steam turbine 9 may be coupled in parallel to drive the turbine generator 25 through a speed reducer using each rotational power.

[0065] Further, an exhaust gas flow rate adjusting valve 33 that controls the flow rate of gas introduced to the power turbine 7 and an emergency shutoff valve 35 that shuts off the supply of exhaust gas to the power turbine 7 in an emergency are provided in the second exhaust gas pipe L2. The exhaust gas flow rate adjusting valve 33 does not have a governor control function. That is, the power turbine 7 is not governor-controlled.

[0066] Further, a governor valve (steam flow rate adjusting valve) 37 that controls the flow rate of steam introduced to the steam turbine 9 and an emergency shutoff valve 39 that shuts off the supply of steam to the steam turbine 9 in an emergency are provided in the first steam pipe J1. An opening degree of the governor valve 37 is controlled by a governor 59 of a power generation system control device 43.

[0067] As described above, the turbine generator system 1 is driven using exhaust energy of the exhaust gas (combustion gas) of the main engine 3 as power, and forms an exhaust energy recovery device.

[0068] Fig. 2 shows a schematic configuration of a power generation system 2 having the turbine generator system 1 shown in Fig. 1.

[0069] The power generation system 2 includes plural (two in this embodiment) diesel engine generators (generators) 60 that are separately provided in a ship, in addition to the turbine generator system 1 (see Fig. 1).

[0070] Further, the power generation system control device 43 which is a control device of the power generation system 2 according to this embodiment performs a control so that the opening degree of the governor valve 37 becomes a predetermined value (a target opening degree), to thereby perform a pressure-changing operation for changing the pressure of steam to be introduced to the steam turbine 9.

[0071] The power generation system control device 43 receives an input of a signal from a power sensor 45 that detects an output power of the turbine generator 25. Further, the power generation system control device 43 receives inputs of an output signal from the diesel engine generator 60 and a signal from an inboard consumed power sensor 51 that detects inboard consumed power.

[0072] Further, the power generation system control device 43 includes a power management system (PMS) 53, a turbine control panel (TCP) 57, and a governor section (governors 87 and 88 in Fig. 3) for the diesel engine generator 60. In addition, the TCP 57 includes the governor 59. The governor 59 controls a rotation speed of the steam turbine 9. That is, the governor 59 controls the output of the steam turbine 9 by outputting the opening degree of the governor valve 37 depending on the speed setting of a rotation speed instructed by the PMS 53 to the governor valve 37.

[0073] An instruction signal of an output depending on a load factor set from the PMS 53 is output to the TCP 57 and the governor section for the diesel engine generator 60, respectively.

[0074] A control signal is output to the governor 59 of the TCP 57 according to an output load ratio of the steam turbine 9 instructed by the PMS 53, and the governor 59 outputs the opening degree of the governor valve 37 according to the control signal to the governor valve 37. Thus, the opening degree of the governor valve 37 is controlled, so that the flow rate of steam supplied to the steam turbine 9 is controlled.

[0075] Here, the power turbine 7, the steam turbine 9, and the turbine generator 25 are coupled in series on one axis. When these components are coupled in series on one axis in this way, only the governor 59 related to the steam turbine 9 which is a main motor is provided as the governor. This is because it is difficult to perform control when two or more governors are provided on one axis.

[0076] Accordingly, when an output from the power turbine 7 is changed, the power generation system control device 43 controls the governor valve 37 according to the output of the steam turbine 9, that is, by the governor 59.

[0077] Here, since the governor is not provided in the power turbine 7, the control of the power turbine 7 becomes only a control for opening and closing the exhaust gas flow rate adjusting valve 33, and a fully opened state is constantly maintained during normal operation. Here, the opening degree of the exhaust gas flow rate adjusting valve 33 is gradually increased or is gradually decreased, only when the power turbine 7 is started or shut down. Accordingly, if there is a change of the output of the power turbine 7, the control of the opening degree of the governor valve 37 due to the output of the steam turbine 9, that is, the governor 59 is changed to absorb the change. The starting of the power turbine 7 refers to a state where the output of the power turbine 7 is increased from 0 which is a starting point, and the shutdown of the power turbine 7 refers to a state where the output of the power turbine 7 is decreased so that the output becomes 0.

[0078] Further, mixed steam (low-pressure steam) from a low pressure steam source 61 is supplied to an intermediate stage of the steam turbine 9. An adjusting valve 62 that controls the flow rate of mixed steam introduced to the steam turbine 9 is provided on a supply line of the mixed steam. The opening degree of the adjusting valve 62 is increased or is decreased according to an increase and decrease in the flow rate of steam generated in the low pressure steam source 61. Accordingly, if there is a change of the flow rate of the supplied mixed steam, the control of the opening degree of the governor valve 37 due to the output of the steam turbine 9, that is, the governor 59 is changed to absorb the change. A low pressure stage (see Fig. 1) of the exhaust gas economizer 11 may be used as the low pressure steam source 61.

[0079] As described above, a control signal according to an output load ratio is output from the PMS 53 to the governor 59 that operates the governor valve 37.

[0080] Next, a governor control according to this embodiment will be described.

[0081] In the governor control according to this embodiment, an actual available power value obtained from the steam turbine 9 is calculated on the basis of a limit value of an available power indicating an output of the steam turbine 9 capable of being used by the turbine generator 25 (hereinafter, referred to as a "limit available power value"), and on the basis of a difference between the target opening degree of the governor valve 37 and an actual opening degree of the governor valve 37, by the TCP 57. Further, the opening degree of the governor valve is controlled by the governor 59 on the basis of the calculated available power value. The target opening degree of the governor valve 37 is an opening degree of 90%, for example, and does not need to be a fully opened state.

[0082] The governor control according to this embodiment will be described in detail with reference to Fig. 3. Fig. 3 is a functional block diagram according to governor controls of the TCP 57 and the PMS 53 according to this embodiment.

[0083] The TCP 57 includes an available power value calculation unit 70 that calculates an available power value to be output to the PMS 53. The available power value calculation unit 70 does not output a pulse signal for increasing or decreasing an available power value that is retained in advance in the PMS 53 to the PMS 53, but calculates an absolute value of the available power value and outputs the result to the PMS 53 as an analog signal (a voltage value).

[0084] The available power value calculation unit 70 includes a limit value calculation unit 71 that calculates a limit available power value.

[0085] The limit value calculation unit 71 calculates a limit value of an available power value (hereinafter, referred to as the "limit available power value") on the basis of a load (M/E load) of the main engine 3, for example, and outputs the result to a multiplier 72. In other words, the limit available power value is an upper limit value of the available power value to be calculated. That is, the upper limit value is set with respect to the available power value calculated by the available power value calculation unit 70. In this way, since the upper limit is set with respect to the available power value, the available power value calculation unit 70 can calculate an available power value based on reality.

[0086] For example, the limit value calculation unit 71 calculates a limit available power value which is logically calculated by a predetermined function that uses a load of the main engine 3 and an outside air temperature (Atomos. Temp.) as variables. The logically calculated limit available power value is, in other words, a design value of an available power value. However, the limit available power value is not limited thereto, and other parameters may be added to the design value to obtain a more realistic value.

[0087] Further, the TCP 57 includes a subtracter 73 and a PID calculation unit 74.

[0088] The subtracter 73 calculates an opening degree difference which is a difference between the target opening degree of the governor valve 37 (GV Lift Setting) and an actual opening degree of the governor valve 37 (GV Lift), and outputs the result to the PID calculation unit 74.

[0089] The PID calculation unit 74 calculates an available power value (hereinafter, referred to as an "opening degree difference available power value") on the basis of the opening degree difference, and outputs the result to a low value selector 75. The PID calculation unit 74 calculates an opening degree difference available power value according to a predetermined function that uses the opening degree difference as a variable.

[0090] The opening degree difference available power value is compared with an available power value (hereinafter, referred to as a "pressure difference available power value") based on a difference between a set value of the pressure of steam to be introduced to the steam turbine 9 and an actual steam pressure by the low value selector 75, and a smaller value is output from the low value selector 75. The available power value output from the low value selector 75 is, in other words, a target value of an available power (hereinafter, referred to as an "available power target value").

[0091] The available power target value output from the low value selector 75 is input to a PID calculation unit 77 through a subtracter 76.

[0092] The subtracter 76 subtracts the available power value output from the multiplier 72 from the available power target value, and outputs the subtraction result value to the PID calculation unit 77. That is, the value output from the multiplier 72 is a current value of the available power target value, and a difference between the target value of the available power and the current value is calculated by the subtracter 76.

[0093] The PID calculation unit 77 calculates an input difference to become a value that is equal to or smaller than 1, and outputs the result to the multiplier 72. That is, the difference between the target value of the available power and the current value is set to be equal to or smaller than 1 by the PID calculation unit 77 so that the calculated available power value does not exceed the limit available power value, and then, is multiplied by the limit available power value by the multiplier 72.

[0094] In this way, the available power value calculation unit 70 calculates an available power value in which a limit available power value is set as an upper limit, on the basis of the difference between the target opening degree of the governor valve 37 and the actual opening degree of the governor valve 37.

[0095] High-pressure steam and low-pressure steam are introduced to the steam turbine 9 according to this embodiment, but with respect to the low-pressure steam, the governor control is not performed. Thus, an available power value output from the multiplier 72 is added to an available power value (LP Avail. kW) based on low-pressure steam which is separately calculated, by an adder 78. An available power value output from the adder 78 is an available power value (ST Avail. kW) of the steam turbine 9 according to this embodiment.

[0096] Further, since the turbine generator system 1 according to this embodiment also includes the power turbine 7, an output value (PT Act. kW) of the power turbine 7 which is separately calculated is also further added by an adder 79. That is, an available power value output from the adder 79 is an absolute value of an actual available power value (STG Avail. kW) of the turbine generator 25 according to this embodiment, and this value is output to a load sharing control unit 80 provided in the PMS 53 as an analog signal (a voltage value).

[0097] Further, the available power value calculation unit 70 according to this embodiment calculates a smaller value among an opening degree difference available power value and a pressure difference available power value as an actual available power value (available power target value) obtained from the steam turbine 9, as described above.

[0098] This is because as a governor valve opening degree is opened, a steam pressure decreases, but since a minimum value is set with respect to the steam pressure, an actual steam pressure does not become a value smaller than the set minimum value. That is, in a case where the pressure difference available power value is smaller than the opening degree difference available power value refers to a case in which the actual steam pressure is smaller than the set minimum value. In such a case, the pressure difference available power value is selected by the low value selector 75, and an available power value capable of maintaining the actual steam pressure to be equal to or greater than the set minimum value is calculated.

[0099] Thus, it is possible to prevent the pressure of steam that is introduced to the steam turbine 9 from being smaller than the set minimum value.

[0100] Thus, in order to calculate a pressure difference available power value, the available power value calculation unit 70 includes a subtracter 81 and a PID calculation unit 82.

[0101] The subtracter 81 calculates a pressure difference which is a difference between a measurement value of a high-pressure steam pressure (HP Press) and a set minimum value of the high-pressure steam pressure (HP Press Min Setting), and outputs the result to the PID calculation unit 82.

[0102] The PID calculation unit 82 calculates a pressure difference available power value on the basis of the pressure difference, and then, outputs the result to the low value selector 75. The PID calculation unit 82 calculates a pressure difference available power value using a predetermined function that uses a pressure difference as a variable.

[0103] If a difference between an actual steam pressure and a set minimum value is excessively large, a temporal change of a calculated available power value also increases. In a case where the governor control is performed using such an available power value, the turbine generator system 1 may greatly change and the control may be unstable. The reason why the control is unstable is that there is a possibility that in a case where the opening degree of the governor valve 37 of the steam turbine 9 rapidly increases, a high-pressure steam pressure rapidly decreases and a circulating water pump (not shown) that circulates water between a high pressure evaporator that is provided between a high pressure drum (not shown) and the exhaust gas economizer 11 causes cavitation. In the high pressure drum (and a circulating water pump inlet pipe), in a case where pressure rapidly decreases compared with the temperature of water (liquid), there is a possibility that water is evaporated to cause cavitation by suction of the circulating water pump.

[0104] In order to prevent the above-mentioned problem, the available power value calculation unit 70 includes a subtracter 83, a high value selector 84, and a rate limiter 85.

[0105] The subtracter 83 subtracts a predetermined change suppression value (a regulating value) from a measurement value of a high-pressure steam pressure. The change suppression value is 0.5 bar, for example.

[0106] The high value selector 84 compares a measurement value obtained by the subtraction of the change suppression value with the set minimum value, and outputs a smaller value to the rate limiter 85.

[0107] The rate limiter 85 outputs the value output from the high value selector 84 to the subtracter 83 at a predetermined temporal change rate.

[0108] Here, in a case where the measurement value of the high-pressure steam pressure is, for example, 6.2 bar, and the set minimum value is, for example, 5.5 bar, the value output from the high value selector 84 is 5.7 bar, and a value output from the subtracter 81 is 0.5 bar. Further, in a case where the measurement value of the high-pressure steam pressure is, for example, 5.8 bar, and the set minimum value is, for example, 5.5 bar, the value output from the high value selector 84 is 5.5 bar, and the value output from the subtracter 81 is 0.3 bar. On the other hand, even in a case where the measurement value of the high-pressure steam pressure is 8.0 bar, since the value output from the high value selector 84 is 7.5 bar, the value output from the subtracter 81 is 0.5 bar. That is, even in a case where a difference between the measurement value of the high-pressure steam pressure and the set minimum value is large, the available power value calculation unit 70 according to this embodiment does not use a difference that exceeds the change suppression value, that is, uses the change suppression value as a regulating value to calculate an available power value as a value which is equal to or smaller than the change suppression value. Thus, a temporal change of the available power value calculated by the available power value calculation unit 70 is suppressed from being greatly changed.

[0109] The available power value (STG Avail. kW) calculated by the TCP 57 in this way is output to the PMS 53 as an analog signal (a voltage value).

[0110] The PMS 53 includes the load sharing control unit 80 and a governor increase/decrease pulse generator 86.

[0111] The load sharing control unit 80 generates a load sharing signal indicating load sharing of the steam turbine 9 and the diesel engine generator 60 on the basis of an available power value input from the TCP 57. The governor increase/decrease pulse generator 86 generates a pulse signal (hereinafter, referred to as a "governor increase/decrease pulse signal") indicating governor increase or governor decrease for increasing or decreasing a control value (speed set value) with respect to the steam turbine 9 and the diesel engine generator 60, on the basis of the load sharing signal from the load sharing control unit 80, and outputs the result to each of the governors 59, 87, and 88.

[0112] The governor 59 is provided in the TCP 57, and controls a rotation speed of the steam turbine 9, and outputs a governor valve opening degree according to a speed set value (governor increase/decrease pulse signal) of a rotation speed instructed by the PMS 53 to the governor valve 37, to thereby control an output of the steam turbine 9 and to perform a control so that the governor valve opening degree becomes a target opening degree.

[0113] Further, the governors 87 and 88 are provided in each corresponding diesel engine generator 60, and control the rotation speed of the diesel engine generator 60. The governors 87 and 88 output the governor valve opening degree according to the speed set value (governor increase/decrease pulse signal) of the rotation speed instructed by the PMS 53 to the governor valve 37, to thereby control the output of the diesel engine generator 60.

[0114] Next, calculation of an output value (PT Act. kW) of the power turbine 7 will be described.

[0115] The available power value (STG Avail. kW) of the turbine generator 25 is a sum of the available power value (ST Avail. kW) of the steam turbine 9 and the output value (PT Act. kW) of the power turbine 7 as described above (Expression (1)).

STG Avail. kW = ST Avail. kW + PT Act. kW ... (1)

[0116] Here, the output value (PT Act. kW) of the power turbine 7 is calculated by subtracting an output measurement value (ST Act. kW) of the steam turbine 9 from an output measurement value (STG Act. kW) of the turbine generator 25, as expressed by Expression (2).

PT Act. kW = STG Act. kW - ST Act. kW ... (2)

[0117] The output measurement value of the steam turbine 9 is calculated by a known method using various measurement values such as a main steam pressure, a steam temperature, or an exhaust pressure of steam that is introduced to the steam turbine 9.

[0118] Further, the reason why the available power value (STG. Avail. kW) of the turbine generator 25 is calculated on the basis of Expression (1) will be hereinafter described in detail.

[0119] It may be considered that the available power value (STG Avail. kW) of the turbine generator 25 is calculated from the following Expression (3) using the available power value (PT Avail. kW) of the power turbine 7.

STG Avail. Kw = ST Avail. kW + PT Avail. kW ... (3)

[0120] Here, the available power value (PT Avail. kW) of the power turbine 7 is obtained by performing correction with respect to a function due to the load of the main engine 3 using an outside air temperature (suction temperature of the turbocharger 5) as a parameter. That is, in Expression (3), since the available power value (PT Avail. kW) of the power turbine 7 is determined to become certain value using the load of the main engine 3 and the outside air temperature, the available power value (PT Avail. kW) of the power turbine 7 that frequently changes during operation of the power turbine 7 cannot be calculated using the load of the main engine 3 and the outside air temperature. Accordingly, in Expression (3), the available power value (STG Avail. kW) of the turbine generator 25 during operation of the power turbine 7 cannot be calculated.

[0121] A method for gradually changing the available power value (PT Avail. kW) of the power turbine 7 in expectation of being close to a change of an actual output value of the power turbine 7 during operation may be considered. However, in a case where there is a difference between the reality and the expectation, if the governor valve 37 of the steam turbine 9 is operated to absorb the difference, there is a possibility that the opening degree of the governor valve 37 of the steam turbine 9 may be greatly moved.

[0122] Thus, by using the output value (PT Act. kW) of the power turbine 7 as it is as in Expression (1), it is possible to reflect the change of the available power value during operation of the power turbine 7 in the available power value (STG Avail. kW) of the turbine generator 25 with high accuracy in real time. Thus, a problem in that the opening degree of the governor valve 37 of the steam turbine 9 is greatly moved as described above does not occur.

[0123] In order to maintain the opening degree of the governor valve 37 of the steam turbine 9 (in other words, an output of the steam turbine 9) as it is, the change of the output value (PT Act. kW) during operation of the power turbine 7 may also be considered as the change of the available power value (STG Avail. kW) of the turbine generator 25. Further, the change of the output during operation of the power turbine 7 is expressed as the change of the PT Act. kW calculated in Expression (2), which may be obtained with high accuracy.

[0124] Fig. 4 shows an example of a functional block diagram relating to calculation of an output value of the power turbine 7 in the available power value calculation unit 70.

[0125] The available power value calculation unit 70 includes a subtracter 90, a subtracter 91, and a PID calculation unit 92.

[0126] The subtracter 90 subtracts an output measurement value (ST Act. kW) of the steam turbine 9 from an output measurement value (STG Act. kW) of the turbine generator 25 to calculate an output value (PT Act. kW) of the power turbine 7.

[0127] The subtracter 91 performs subtraction between the output value (PT Act. kW) from the subtracter 90 and an available power value of the power turbine 7 output from the PID calculation unit 92, and outputs a difference. A case in which the difference output from the subtracter 91 is not zero corresponds to a case in which there is a change of the output of the power turbine 7.

[0128] The PID calculation unit 92 calculates the available power value of the power turbine 7 on the basis of the difference output from the subtracter 91, and outputs the result to the adder 79. In a case where there is a change of the output of the power turbine 7 and a large difference value is input, the PID calculation unit 92 does not rapidly change the output value of the power turbine 7, but gradually changes the output value (available power value) of the power turbine 7 according to temporal changes and outputs the result.

[0129] By calculating the output value of the power turbine 7 in this way, the change of the output of the power turbine 7 in a case where the load of the main engine 3 changes appears as an absolute value (analog signal).

[0130] Here, in the related-art control using a pulse signal, since the governor valve 37 of the steam turbine 9 is controlled every time according to a change of an output of the power turbine 7 and a change of an available power value in the PMS 53, while a condition of a plant is being changed, the opening degree of the governor valve is excessively decreased or is fixed at a fully opened position, and thus, there is a possibility that the control becomes unstable.

[0131] On the other hand, in this embodiment, the change of the output of the power turbine 7 is reflected in the available power value of the turbine generator 25 in real time. Thus, the PMS 53 can calculate load sharing of each inboard power generator without a time lag using the calculated available power value (STG Avail. kW) although the output of the power turbine 7 changes, and can output a command (a governor increase/decrease pulse signal) for instructing each power generator to increase or decrease of the opening degree of the governor valve. That is, since the calculated available power value of the turbine generator 25 can be calculated without a time lag although the output of the power turbine 7 changes, it is possible to stabilize the control of the opening degree of the governor valve. Further, although the output of the power turbine 7 changes, it is possible to perform more stable control without greatly changing the opening degree of the governor valve.

[0132] Next, a pressure-changing operation of the turbine generator system 1 according to this embodiment will be specifically described with reference to Figs. 5 to 8.

[0133] Fig. 5 is a graph illustrating temporal changes of various control values in a pressure-changing operation. Here, Fig. 5(A) shows a temporal change of a load of the main engine 3, Fig. 5(B) shows a temporal change (solid line) of the opening degree of the governor valve of the steam turbine 9 and a temporal change (broken line) of the opening degree of the dump valve 41, Fig. 5(C) shows a temporal change of a high-pressure steam pressure, and Fig. 5(D) shows a temporal change of the output of the turbine generator 25. A transverse axis (time) in Fig. 5 is divided into periods (1) to (14), for ease of description.

[0134] First, a case in which the load of the main engine 3 increases will be described for each of periods (1) to (8).

[0135] Period (1) : An operation of the main engine 3 is started, and the exhaust gas economizer 11 is operated, so that generation of high-pressure steam is started and the pressure rises.

[0136] Period (2): If the high-pressure steam pressure rises to a set pressure of the dump valve 41, the dump valve 41 is opened, and the opening degree of the dump valve 41 is controlled so that the high-pressure steam pressure becomes a predetermined pressure according to increase of the flow rate of steam.

[0137] Period (3): An operation of the steam turbine 9 is started. Further, according to increase of the opening degree of the governor valve 37 or according to increase of load, the steam is introduced to the steam turbine 9. Accordingly, the opening degree of the dump valve 41 decreases, and then, the dump valve 41 is fully closed. That is, during the period (1) to the period (3), the high-pressure steam pressure is controlled by the dump valve 41.

[0138] In addition, since the high-pressure steam pressure exceeds a set minimum value up to the period (3) and the opening degree of the governor valve is smaller than a target opening degree, the TCP 57 increase an available power value to be output to the PMS 53.

[0139] The PMS 53 outputs a pulse signal indicating a governor increase command to the governor 59 according to the increased available power value. Thus, the governor 59 increases the opening degree of the governor valve, and thus, the load of the steam turbine 9 increases.

[0140] Period (4): As the dump valve 41 is fully closed and the opening degree of the governor valve increases, the high-pressure steam pressure decreases. Operations of the TCP 57 and the PMS 53 and a change of the available power value in the period (4) are the same as in the period (3).

[0141] Period (5): While the opening degree of the governor valve is being increased to become a target opening degree, if the high-pressure steam pressure decreases to reach the set minimum value, the opening degree of the governor valve is controlled to maintain the set minimum value. Further, as the flow rate of steam increases, the opening degree of the governor valve increases while maintaining the set minimum value.

[0142] If the high-pressure steam pressure is smaller than the set minimum value, although the opening degree of the governor valve does not reach the target opening degree, the TCP 57 stops the increase of the available power value up to then, and adjusts the available power value to maintain the set minimum value.

[0143] Period (6): If the opening degree of the governor valve reaches the target opening degree, the control of the opening degree is stopped, and thereafter, if the flow rate of steam increases, the high-pressure steam pressure increases in a state where the target opening degree of the governor valve 37 is maintained.

[0144] The control for maintaining the opening degree of the governor valve at the target opening degree is temporarily stopped, but strictly speaking, since if the flow rate of steam increases in this state, the rotation speed of the steam turbine 9 increases, the governor 59 is operated to reduce the flow rate of steam to be introduced to the steam turbine 9, and thus, the opening degree of the governor valve decreases. Further, the TCP 57 increases the available power value in order to further maintain the opening degree of the governor valve at the target opening degree, and the load increases according to a governor increase command of the PMS 53. In this way, even after reaching the target opening degree of the governor valve 37, according to the increase of the flow rate of steam, the available power value increases while repeating the control for maintaining the opening degree of the governor valve at the target opening degree, and the load of the steam turbine 9 increases.

[0145] Period (7): The operation of the power turbine 7 is started. The opening degree of the governor valve also transiently changes according to the increase of the output of the power turbine 7, but since the available power value is controlled so that the change does not become large, the change is not shown in the figure.

[0146] Period (8): According to the increase of the output of the power turbine 7 due to the increase of the load of the main engine 3, and according to the increase of the flow rate of steam, until the governor increase command is received from the PMS 53, the opening degree of the governor valve is controlled to be reduced, and the available power value and the load of the steam turbine 9 increase in the same movement as in the period (6). If the opening degree of the governor valve decreases to be smaller than the target opening degree, the TCP 57 increases the available power value (STG Avail. kW) of the turbine generator 25 to return the opening degree of the governor valve to the target opening degree. In addition, the governor increase command is received from the PMS 53, and thus, the opening degree of the governor valve increases toward the target opening degree. In this way, in the period (8), the opening degree of the governor valve maintains the target opening degree while repeating slight increase or decrease.

[0147] Next, a case in which the load of the main engine 3 decreases will be described for each of periods (11) to (14).

[0148] Period (11): According to the increase of the output of the power turbine 7 due to the decrease of the load of the main engine 3, and according to the decrease of the flow rate of steam, until a governor decrease command is received from the PMS 53, the opening degree of the governor valve increases to compensate for speed reduction of the steam turbine 9. On the other hand, the TCP 57 decreases the available power value to return the opening degree of the governor valve to the target opening degree, and the load decreases due to the governor decrease command of the PMS 53.

[0149] If the opening degree of the governor valve increases to be larger than the target opening degree, the TCP 57 decreases the available power value (STG Avail. kW) of the turbine generator 25 in order to return the opening degree of the governor valve to the target opening degree. Further, the governor decrease command is received from the PMS 53, and thus, the opening degree of the governor valve decreases toward the target opening degree. In this way, in the period (11), the opening degree of the governor valve maintains the target opening degree while repeating slight increase or decrease.

[0150] Period (12): The power turbine 7 is stopped. Generally, the power turbine 7 is stopped due to reduction of an extraction gas allowance due to reduction of the load of the main engine 3. The opening degree of the governor valve also transiently changes according to reduction of the output of the power turbine 7 and the stop thereof, but since the available power value is controlled so that the change does not become large, the change is not shown in the figure.

[0151] Period (13): According to the reduction of the flow rate of steam due to further reduction of the load of the main engine 3, the opening degree of the governor valve is maintained at the target opening degree, and the high-pressure steam pressure decreases to the set minimum value. Then, since the available power value is reduced to maintain the set minimum value of the high-pressure steam pressure, the opening degree of the governor valve decreases.

[0152] Period (14): If the available power value reaches a predetermined minimum value, the available power value does not decrease any more, and the PMS 53 gives a command (for example, an increase command) to the governor 59 to secure a load of the minimum value, and thus, the high-pressure steam pressure begins to decrease to become smaller than the set minimum value. Then, according to the decrease of the output and the decrease of the high-pressure steam pressure, the steam turbine 9 is stopped.

[0153] Figs. 6A and 6B are graphs illustrating temporal changes of various control values in the related art when the power turbine 7 is operated, and temporal changes of various control values according to an embodiment of the invention. Fig. 6A shows temporal changes of various control values in the related art, and Fig. 6B shows temporal changes of various control values according to the embodiment of the invention. Further, a time T_1 represents a timing when the exhaust gas flow rate adjusting valve 33 is opened to operate the power turbine 7, a time T_2 represents a timing when the clutch 31 of the power turbine 7 is turned on so that the power turbine 7 is connected to the turbine generator 25, a time T_3 represents a timing when the output of the power turbine 7 becomes constant in this embodiment, and a time T_4 represents a timing when the exhaust gas flow rate adjusting valve 33 is fully opened.

[0154] (A-1) of Fig. 6A and (B-1) of Fig. 6B show temporal changes of the load of the main engine 3, and in Figs. 6A and 6B, a case in which the load of the main engine 3 is constant is shown, as an example.

[0155] (A-2) of Fig. 6A and (B-2) of Fig. 6B show temporal changes of the opening degree of the exhaust gas flow rate adjusting valve 33. The opening degree of the exhaust gas flow rate adjusting valve 33 is continuously changed from a fully closed position to a fully opened position during the time T_1 to the time T_4.

[0156] (A-3) of Fig. 6A and (B-3) of Fig. 6B show temporal changes of the available power value (an available power value of the turbine generator 25) in the PMS 53. In (A-3) of Fig. 6A in the related art, since the available power value is increased or decreased by a pulse signal, the available power value increases in stages over time. On the other hand, in (B-3) of Fig. 6B according to this embodiment, since the available power value is expressed by an analog signal, the available power value continuously increases.

[0157] In the increase of the available power value using the pulse signal in the related art, even after the time T_3 when the output of the power turbine 7 becomes constant, the available power value increases in stages due to a time lag. On the other hand, in the control according to this embodiment, at the timing of the time T_3 when the output of the power turbine 7 becomes constant, the increase of the available power value is terminated, and thereafter, the available power value becomes constant.

[0158] (A-4) of Fig. 6A and (B-4) of Fig. 6B show temporal changes of a governor speed set value with respect to the steam turbine 9.

[0159] Since the change of the governor speed set value depends on increase or decrease of the available power value, in (A-4) of Fig. 6A in the related art, even after the time T_3 when the output of the power turbine 7 becomes constant, the governor speed set value increases in stages by a predetermined value due to a time lag. On the other hand, in (B-4) of Fig. 6B according to this embodiment, at the timing of the time T_3 when the output of the power turbine 7 becomes constant, the increase of the governor speed set value is terminated, and thereafter, the governor speed set value becomes constant.

[0160] (A-5) of Fig. 6A and (B-5) of Fig. 6B show temporal changes of the opening degree of the governor valve. Further, (A-6) of Fig. 6A and (B-6) of Fig. 6B show temporal changes of the output of the steam turbine 9, the output of the power turbine 7, and the output of the turbine generator 25.

[0161] As shown in (A-5) of Fig. 6A and (B-5) of Fig. 6B, as the output of the power turbine 7 increases, the opening degree of the governor valve decreases. This corresponds to a period "a". On the other hand, a control for setting an excessively reduced opening degree of the governor valve to the target opening degree is performed in a period "b".

[0162] In the related art, the opening degree of the governor valve is controlled according to the change of the output of the power turbine 7, and thereafter, a control for setting the opening degree of the governor valve retained in the PMS 53 by a pulse signal or a steam pressure to a target value is performed. Thus, a time lag occurs in the control, and although the exhaust gas flow rate adjusting valve 33 is fully opened, the power turbine 7 or the steam turbine 9 does not become a settling state either.

[0163] On the other hand, in this embodiment, as expressed by Expression (1), since the change of the output of the power turbine 7 is reflected in the available power value (analog signal) of the turbine generator 25 in real time, it is possible to perform the control of the opening degree of the governor valve without a time lag, and to shorten a time (period "b") necessary for the control for setting an excessively reduced opening degree of the governor valve to the target opening degree compared with that in the related art. Particularly, in this embodiment, at a timing when the exhaust gas flow rate adjusting valve 33 is fully opened, since the opening degree of the governor valve can be set to the target opening degree, the power turbine 7 or the steam turbine 9 become the settling state earlier than in the related art.

[0164] Figs. 7A and 7B are a graph illustrating temporal changes of various control values in the related art when the power turbine is stopped, and a graph illustrating temporal changes of various control values according to an embodiment of the invention. Fig. 7A shows temporal changes of various control values in the related art, and Fig. 7B shows temporal changes of various control values according to the embodiment of the invention. Further, a time T_5 represents a timing when the exhaust gas flow rate adjusting valve 33 is closed, a time T_6 represents a timing when the clutch 31 of the power turbine 7 is turned off so that the power turbine 7 is disconnected from the turbine generator 25, a time T_7 represents a timing when the exhaust gas flow rate adjusting valve 33 is fully closed.

[0165] (A-1) of Fig. 7A and (B-1) of Fig. 7B show temporal changes of the load of the main engine 3, and in Figs. 7, a case in which the load of the main engine 3 becomes constant is shown, as an example.

[0166] (A-2) of Fig. 7A and (B-2) of Fig. 7B show temporal changes of the opening degree of the exhaust gas flow rate adjusting valve 33. The opening degree of the exhaust gas flow rate adjusting valve 33 is continuously changed from a fully opened position to a fully closed position during the time T_5 to the time T_7.

[0167] (A-3) of Fig. 7A and (B-3) of Fig. 7B show temporal changes of the available power value (the available power value of the turbine generator 25) in the PMS 53. In (A-3) of Fig. 7A in the related art, since the available power value is increased or decreased by a pulse signal, the available power value decreases in stages. In (A-3) of Fig. 7A, the available power value of the turbine generator 25 excessively decreases due to a time lag of the increase or decrease of the available power value due to the pulse signal, and thereafter, the available power value is changed to increase and becomes constant.

[0168] On the other hand, in (B-3) of Fig. 7B according to this embodiment, since the available power value is expressed by an analog signal, the available power value continuously decreases without a time lag.

[0169] (A-4) of Fig. 7A and (B-4) of Fig. 7B show temporal changes of the governor speed set value with respect to the steam turbine 9.

[0170] Since the change of the governor speed set value depends on the increase or decrease of the available power value, in (A-4) of Fig. 7A in the related art, the governor speed set value decreases, and thereafter, increases and becomes constant. On the other hand, in (B-4) of Fig. 7B according to this embodiment, there is no increase or decrease of the governor speed set value as in the related art, and the governor speed set value decreases and then becomes constant.

[0171] (A-5) of Fig. 7A and (B-5) of Fig. 7B show temporal changes of the opening degree of the governor valve. Further, (A-6) of Fig. 7A and (B-6) of Fig. 7B show temporal changes of the output of the steam turbine 9, the output of the power turbine 7, and the output of the turbine generator 25.

[0172] In the related art, since there is a time lag in the control, it takes time until the output of the turbine generator 25 becomes a settling state. On the other hand, in this embodiment, since the control is possible without a time lag, a time until the output of the turbine generator 25 becomes the settling state is shorter than the time in the related art.

[0173] Figs. 8A and 8B are a graph illustrating temporal changes of various control values in the related art when an inboard power load increases, and a graph illustrating temporal changes of various control values according to an embodiment of the invention. Fig. 8A shows temporal changes of various control values in the related art, and Fig. 8B shows temporal changes of various control values according to the embodiment of the invention. Further, a time T_{10} represents a timing when an inboard power load increases.

[0174] (A-1) of Fig. 8A and (B-1) of Fig. 8B show temporal changes of the load of the main engine 3, and in Figs. 8A and 8B, a case in which the load of the main engine 3 becomes constant is shown, as an example.

[0175] (A-2) of Fig. 8A and (B-2) of Fig. 8B show temporal changes of the opening degree of the governor valve, (A-3) of Fig. 8A and (B-3) of Fig. 8B show temporal changes of the available power value (the available power value of the turbine generator 25) in the PMS 53, (A-4) of Fig. 8A and (B-4) of Fig. 8B show temporal changes of the governor speed set value with respect to the steam turbine 9, and (A-5) of Fig. 8A and (B-5) of Fig. 8B show temporal changes of the output of the steam turbine 9, the output of the power turbine 7, and the output of the turbine generator 25.

[0176] If the inboard power load increases at the time T_{10}, the opening degree of the governor valve accordingly increases, and the output of the turbine generator 25 also increases. On the other hand, since the opening degree of the governor valve increases, the available power value decreases to set the opening degree of the governor valve to the target opening degree. As the available power value is changed, the governor speed set value and the output value of the turbine generator 25 are also changed.

[0177] Here, in the related art, since the available power value retained in the PMS 53 is increased or decreased by a pulse signal, a delay occurs in the change of the available power value with respect to the output change of the turbine generator 25. As a result, since a delay occurs in the change of the governor speed set value or the opening degree of the governor valve, as shown in (A-2) to (A-5) of Fig. 8A, there is a possibility that hunting occurs in various control values. In other words, since a phase of the change of the available power value according to the pulse signal deviates from a phase of the change of the output of the turbine generator 25, the governor speed set value or the opening degree of the governor valve, there is a possibility that hunting occurs.

[0178] On the other hand, in this embodiment, since the TCP 57 calculates an absolute value of the available power value and outputs the result to the PMS 53 using an analog signal, since the calculation of the available power value, the output of the governor speed set value, and the control of the opening degree of the governor valve can be performed without a time lag, and thus, it is possible to prevent such hunting as in the related art.

[0179] As described above, the TCP 57 according to this embodiment performs a control so that the opening degree of the governor valve 37 becomes a predetermined value (a target opening degree), to thereby perform a pressure-changing operation for changing the pressure of steam to be introduced to the steam turbine 9. Further, the TCP 57 calculates an actual available power value obtained from the steam turbine 9 on the basis a difference between the target opening degree of the governor valve 37 and an actual opening degree of the governor valve 37, and controls the opening degree of the governor valve on the basis of the calculated available power value.

[0180] Thus, since the TCP 57 according to this embodiment does not increase or decrease the available power value used in control of the opening degree of the governor valve using a pulse signal as in the related art, it is possible to control the governor valve 37 without the occurrence of a time lag specific to such a pulse signal. Accordingly, the TCP 57 can perform more stable control in exhaust heat recovery in a case where a condition of a plant is changed.

[0181] Hereinbefore, the embodiments of the invention have been described, but a technical scope of the invention is not limited to the scopes disclosed in the embodiments. Various changes or improvements may be added to the embodiments in a range without departing from the concept of the invention, and the embodiments to which the changes or improvements are added may also be included in the technical scope of the invention.

[0182] For example, in the embodiments, a configuration in which the turbine generator system 1 according to this embodiment is used as a power generation system for a ship has been described, but the invention is not limited thereto, and a configuration in which the turbine generator system 1 according to this embodiment is applied to overland plant facilities may be used, for example.

[0183] In this case, the plant facilities may be operated by a so-called microgrid (also referred to as an island mode), which is not connected to an infinite bus.

[0184] Further, in the embodiments, for example, a configuration in which exhaust gas is generated by the main engine 3 has been described, but the invention is not limited to thereto, and a configuration in which exhaust gas is generated by a device other than the main engine 3, for example, is generated by a boiler may be used. Reference Signs List

[0185]

2 POWER GENERATION SYSTEM
3 MAIN ENGINE
7 POWER TURBINE
9 STEAM TURBINE
25 TURBINE GENERATOR (GENERATOR)
37 GOVERNOR VALVE
43 POWER GENERATION SYSTEM CONTROL DEVICE (CONTROL DEVICE)
59 GOVERNOR (CONTROL MEANS)
70 AVAILABLE POWER VALUE CALCULATION UNIT (CALCULATION UNIT)

Claims

1. A control device for a power generation system that includes a steam turbine that is driven by steam generated by exhaust gas, a governor valve that controls the flow rate of steam that is introduced to the steam

turbine, and a generator that is connected to the steam turbine, and performs a pressure-changing operation for changing the pressure of the steam that is introduced to the steam turbine, the control device for a power generation system comprising:

calculation means for calculating an actual available power value obtained from the steam turbine on the basis of a difference between a target opening degree of the governor valve and an actual opening degree of the governor valve; and
control means for controlling an opening degree of the governor valve on the basis of the available power value calculated by the calculation means.

2. The control device for a power generation system according to claim 1,
wherein the available power value calculated by the calculation means has a predetermined upper limit value.

3. The control device for a power generation system according to claim 1 or 2,
wherein the calculation means calculates a smaller value among a first available power value based on the difference between the target opening degree of the governor valve and the actual opening degree of the governor valve and a second available power value based on a difference between a set value of the pressure of the steam that is introduced to the steam turbine and an actual steam pressure, as an actual available power value obtained from the steam turbine.

4. The control device for a power generation system according to claim 1, further including a power turbine that is driven by the exhaust gas,
wherein the generator is connected to the power turbine and the steam turbine, and
wherein the calculation means outputs a sum of the calculated available power value and an output value of the power turbine as an available power value capable of being used by the generator.

5. The control device for a power generation system according to claim 4,
wherein the output value of the power turbine is calculated by subtracting a calculation value of an output of the steam turbine from a measurement value of an output of the generator.

6. A control device for a power generation system that includes a power turbine that is driven by exhaust gas, a steam turbine that is driven by steam generated by the exhaust gas, a governor valve that controls the flow rate of steam that is introduced to the steam turbine, and a generator that is connected to the power turbine and the steam turbine, and performs a pressure-changing operation for changing the pressure of the steam that is introduced to the steam turbine, the control device for a power generation system comprising:

calculation means for calculating an output value of the power turbine by subtracting a calculation value of an output of the steam turbine from a measurement value of an output of the generator and calculating an available power value of the generator by adding the calculated output value of the power turbine to an available power value obtained from the steam turbine; and
control means for controlling an opening degree of the governor valve on the basis of the available power value of the generator calculated by the calculation means.

7. A power generation system comprising the control device according to claim 1 or claim 6,
wherein the power generation system performs a pressure-changing operation for changing the pressure of steam that is introduced to the steam turbine.

8. A power generation method that includes a step of driving a steam turbine by steam generated by exhaust gas, a step of controlling the flow rate of steam that is introduced to the steam turbine using a governor valve, and a step of performing power generation by driving of the steam turbine, and performs a pressure-changing operation for changing the pressure of the steam that is introduced to the steam turbine, the power generation method comprising:

a first step of calculating an actual available power value obtained from the steam turbine on the basis of a difference between a target opening degree of the governor valve and an actual opening degree of the governor valve;
a second step of controlling an opening degree of the governor valve on the basis of the available power value calculated in the first step.

9. A power generation method that includes a step of driving a power turbine by exhaust gas, a step of driving a steam turbine by steam generated by the exhaust gas, a step of controlling the flow rate of steam that is introduced to the steam turbine, and a step of performing power generation by driving of the power turbine and the steam turbine using a governor valve, and performs a pressure-changing operation for changing the pressure of the steam that is introduced to the steam turbine, the power generation method comprising:

a first step of calculating an output value of the power turbine by subtracting a calculation value of an output of the steam turbine from a measurement value of an output of the generator and calculating an available power value of the generator by adding the calculated output value of the power turbine to an available power value obtained from the steam turbine; and
a second step of controlling an opening degree of the governor valve on the basis of the available power value of the generator calculated in the first step.

Amended claims under Art. 19.1 PCT

1. (Amended) A control device for a power generation system that includes a steam turbine that is driven by steam generated by exhaust gas, a governor valve that controls the flow rate of steam that is introduced to the steam turbine, and a generator that is connected to the steam turbine, and performs a pressure-changing operation for changing the pressure of the steam that is introduced to the steam turbine, the control device for a power generation system comprising:

calculation means for calculating an actual available power value obtained from the steam turbine on the basis of a difference between a target opening degree of the governor valve and an actual opening degree of the governor valve; and
control means for controlling an opening degree of the governor valve on the basis of the available power value calculated by the calculation means,
wherein the calculation means calculates a smaller value among a first available power value based on the difference between the target opening degree of the governor valve and the actual opening degree of the governor valve and a second available power value based on a difference between a set value of the pressure of the steam that is introduced to the steam turbine and an actual steam pressure, as an actual available power value obtained from the steam turbine.

2. The control device for a power generation system according to claim 1,
wherein the available power value calculated by the calculation means has a predetermined upper limit value.

3. Deleted)

4. (Amended) The control device for a power generation system according to claim 1, further including a power turbine that is driven by the exhaust gas,
wherein the generator is connected to the power turbine and the steam turbine, and
wherein the calculation means outputs a sum of the calculated available power value and an output value of the power turbine as an available power value capable of being used by the generator.

5. (Amended) The control device for a power generation system according to claim 3,
wherein the output value of the power turbine is calculated by subtracting a calculation value of an output of the steam turbine from a measurement value of an output of the generator.

6. (Amended) A control device for a power generation system that includes a power turbine that is driven by exhaust gas, a steam turbine that is driven by steam generated by the exhaust gas, a governor valve that controls the flow rate of steam that is introduced to the steam turbine, and a generator that is connected to the power turbine and the steam turbine, and performs a pressure-changing operation for changing the pressure of the steam that is introduced to the steam turbine, the control device for a power generation system comprising:

first calculation means for calculating an actual available power value obtained from the steam turbine on the basis of a difference between a target opening degree of the governor valve and an actual opening degree of the governor valve;
first control means for controlling an opening degree of the governor valve on the basis of the available power value calculated by the first calculation means;
second calculation means for calculating an output value of the power turbine by subtracting a calculation value of an output of the steam turbine from a measurement value of an output of the generator and calculating an available power value of the generator by adding the calculated output value of the power turbine to an available power value obtained from the steam turbine; and
second control means for controlling the opening degree of the governor valve on the basis of the available power value of the generator calculated by the second calculation means,
wherein the first calculation means calculates a smaller value among a first available power value based on the difference between the target opening degree of the governor valve and the actual opening degree of the governor valve and a second available power value based on a difference between a set value of the pressure of the steam that is introduced to the steam turbine

and an actual steam pressure, as an actual available power value obtained from the steam turbine.

7. (Amended) A power generation system comprising the control device according to claim 1 or claim 5, wherein the power generation system performs a pressure-changing operation for changing the pressure of steam that is introduced to the steam turbine.

8. (Amended) A power generation method that includes a step of driving a steam turbine by steam generated by exhaust gas, a step of controlling the flow rate of steam that is introduced to the steam turbine using a governor valve, a step of performing power generation by driving of the steam turbine, and performs a pressure-changing operation for changing the pressure of the steam that is introduced to the steam turbine, the power generation method comprising:

a first step of calculating an actual available power value obtained from the steam turbine on the basis of a difference between a target opening degree of the governor valve and an actual opening degree of the governor valve;
a second step of controlling an opening degree of the governor valve on the basis of the available power value calculated in the first step; and
a third step of calculating a smaller value among a first available power value based on the difference between the target opening degree of the governor valve and the actual opening degree of the governor valve and a second available power value based on a difference between a set value of the pressure of the steam that is introduced to the steam turbine and an actual steam pressure, as an actual available power value obtained from the steam turbine.

9. (Amended) A power generation method that includes a step of driving a power turbine by exhaust gas, a step of driving a steam turbine by steam generated by the exhaust gas, a step of controlling the flow rate of steam that is introduced to the steam turbine using a governor valve, a step of performing power generation by driving of the power turbine and the steam turbine, and performs a pressure-changing operation for changing the pressure of the steam that is introduced to the steam turbine, the power generation method comprising:

a first step of calculating an actual available power value obtained from the steam turbine on the basis of a difference between a target opening degree of the governor valve and an actual opening degree of the governor valve;
a second step of controlling an opening degree of the governor valve on the basis of the available power value calculated by the first step;
a third step of calculating an output value of the power turbine by subtracting a calculation value of an output of the steam turbine from a measurement value of an output of the generator and calculates an available power value of the generator by adding the calculated output value of the power turbine to an available power value obtained from the steam turbine;
a fourth step of controlling the opening degree of the governor valve on the basis of the available power value of the generator calculated by the first step; and
a fifth step of calculating a smaller value among a first available power value based on the difference between the target opening degree of the governor valve and the actual opening degree of the governor valve and a second available power value based on a difference between a set value of the pressure of the steam that is introduced to the steam turbine and an actual steam pressure, as an actual available power value obtained from the steam turbine.

FIG. 1

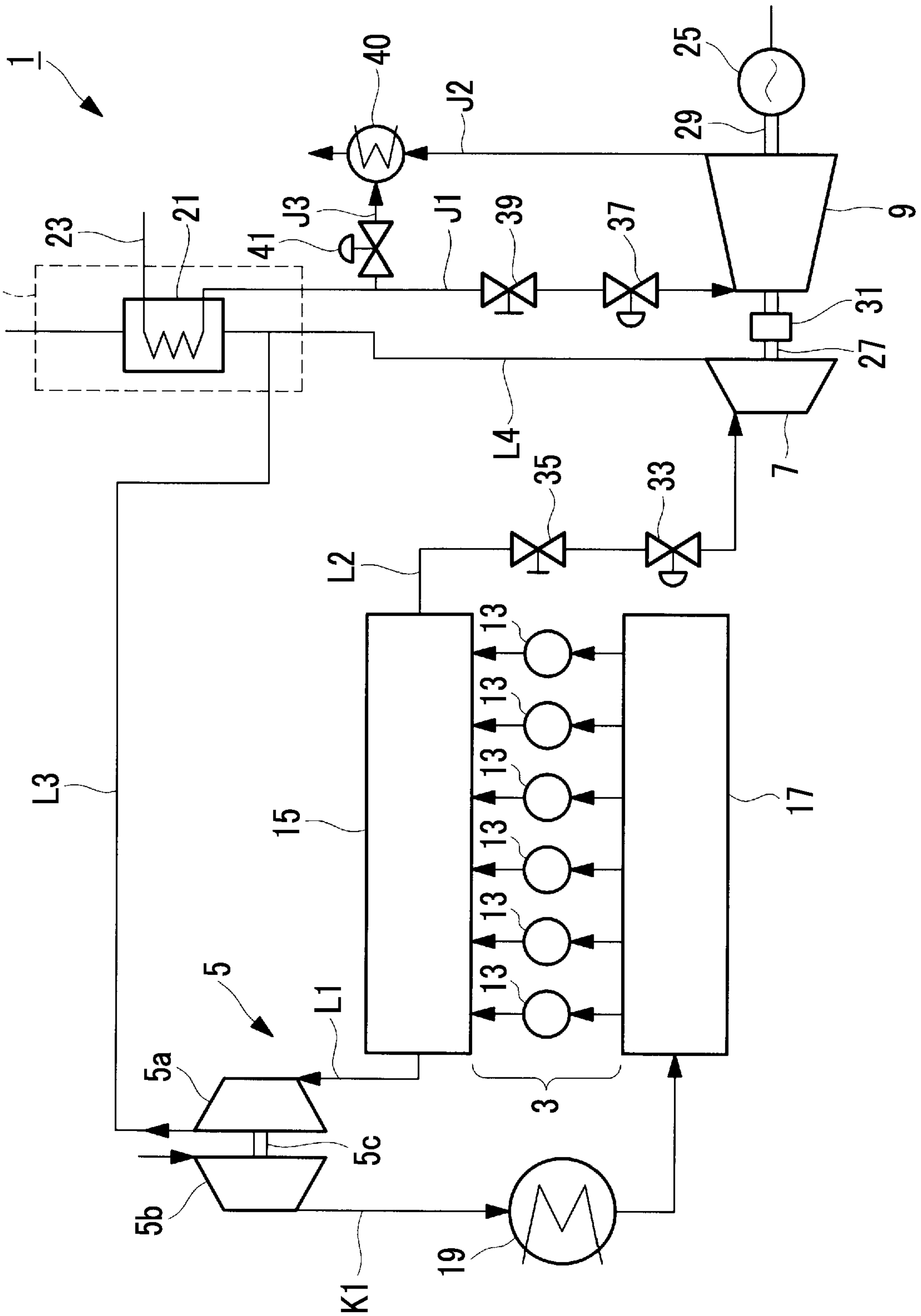

1
5
5a
5b
5c
3
7
9
11
13
15
17
19
21
23
25
27
29
31
33
35
37
39
40
41
L1
L2
L3
L4
J1
J2
J3
K1

FIG. 2

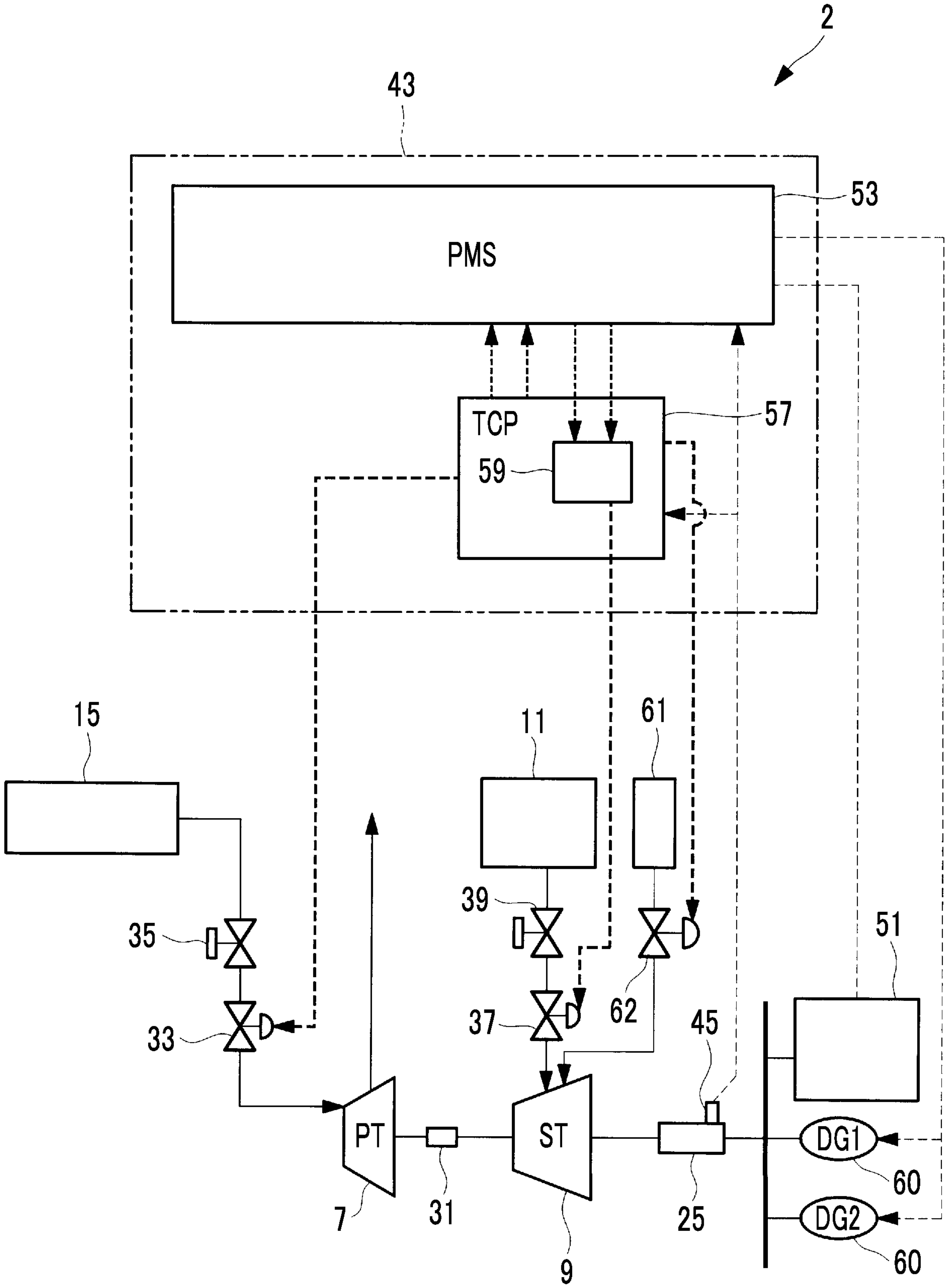

2
43
PMS
53
TCP
57
59
15
11
61
39
35
33
37
62
51
45
PT
ST
DG1
DG2
60
60
7
31
9
25

FIG. 3

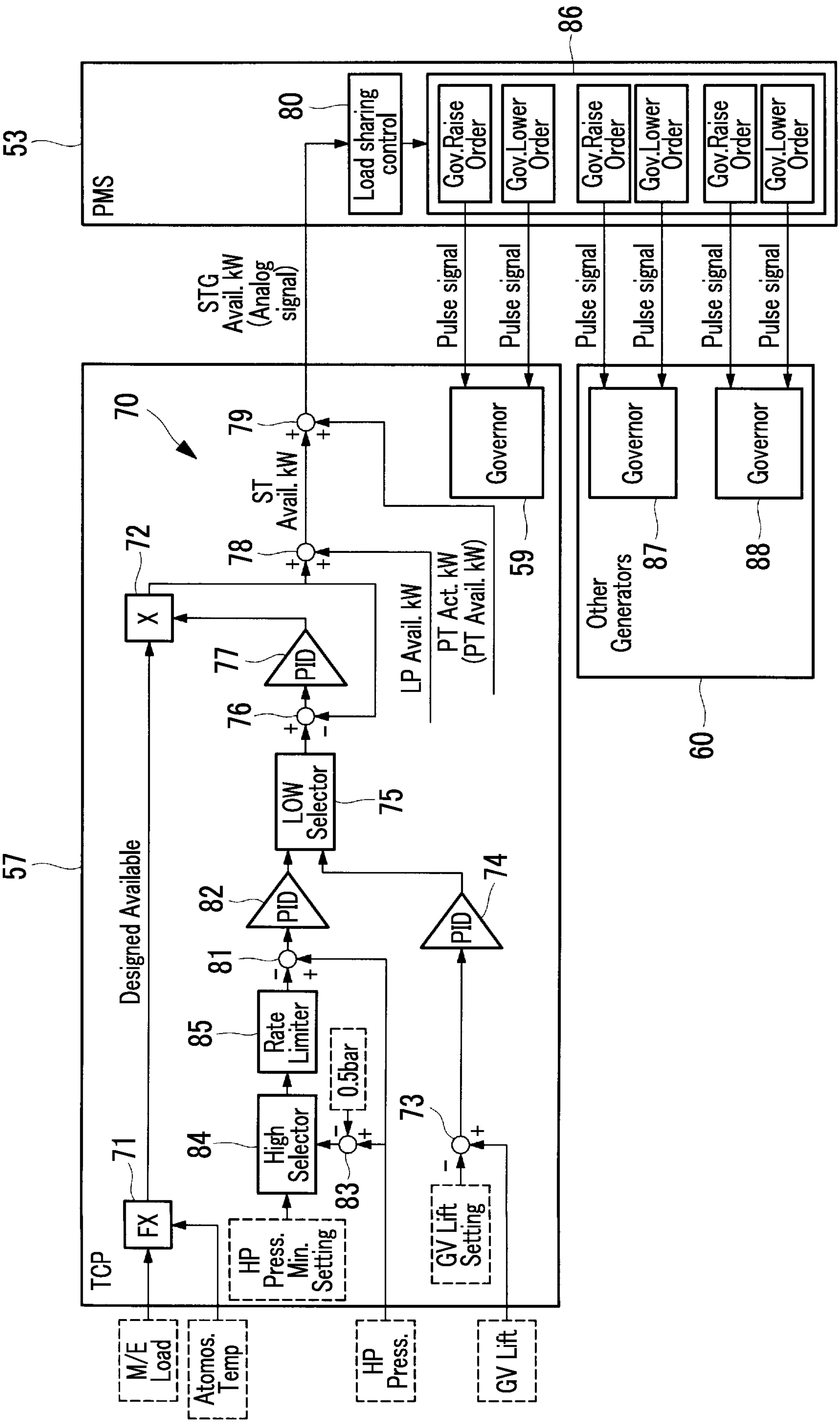

53
PMS
80
Load sharing control
86
Gov.Raise Order
Gov.Lower Order
Gov.Raise Order
Gov.Lower Order
Gov.Raise Order
Gov.Lower Order
STG Avail. kW (Analog signal)
Pulse signal
Pulse signal
Pulse signal
Pulse signal
Pulse signal
Pulse signal
57
TCP
70
79
ST Avail. kW
78
72
X
77
PID
76
LOW Selector
75
LP Avail. kW
PT Act. kW (PT Avail. kW)
Governor
59
Governor
Governor
Other Generators
87
88
60
Designed Available
82
PID
74
PID
81
85
Rate Limiter
0.5bar
84
High Selector
83
73
71
FX
HP Press. Min. Setting
GV Lift Setting
M/E Load
Atomos. Temp
HP Press.
GV Lift

FIG. 4

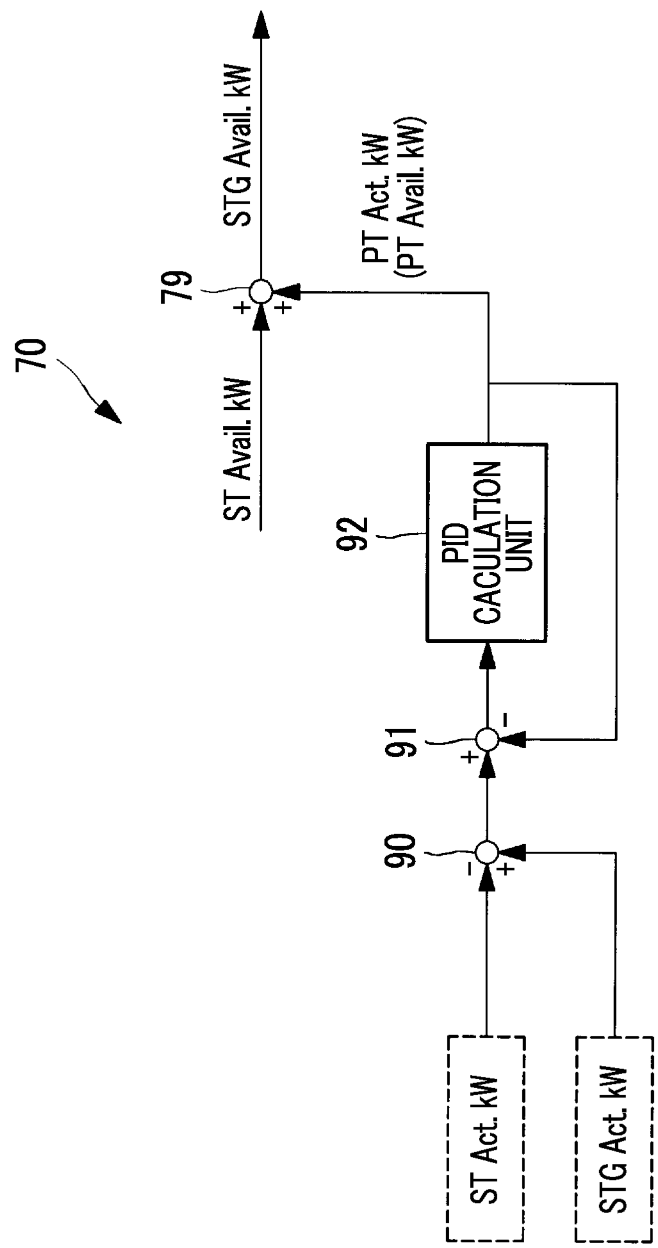

70
79
STG Avail. kW
PT Act. kW
(PT Avail. kW)
ST Avail. kW
92
PID
CACULATION
UNIT
91
90
ST Act. kW
STG Act. kW

FIG. 5

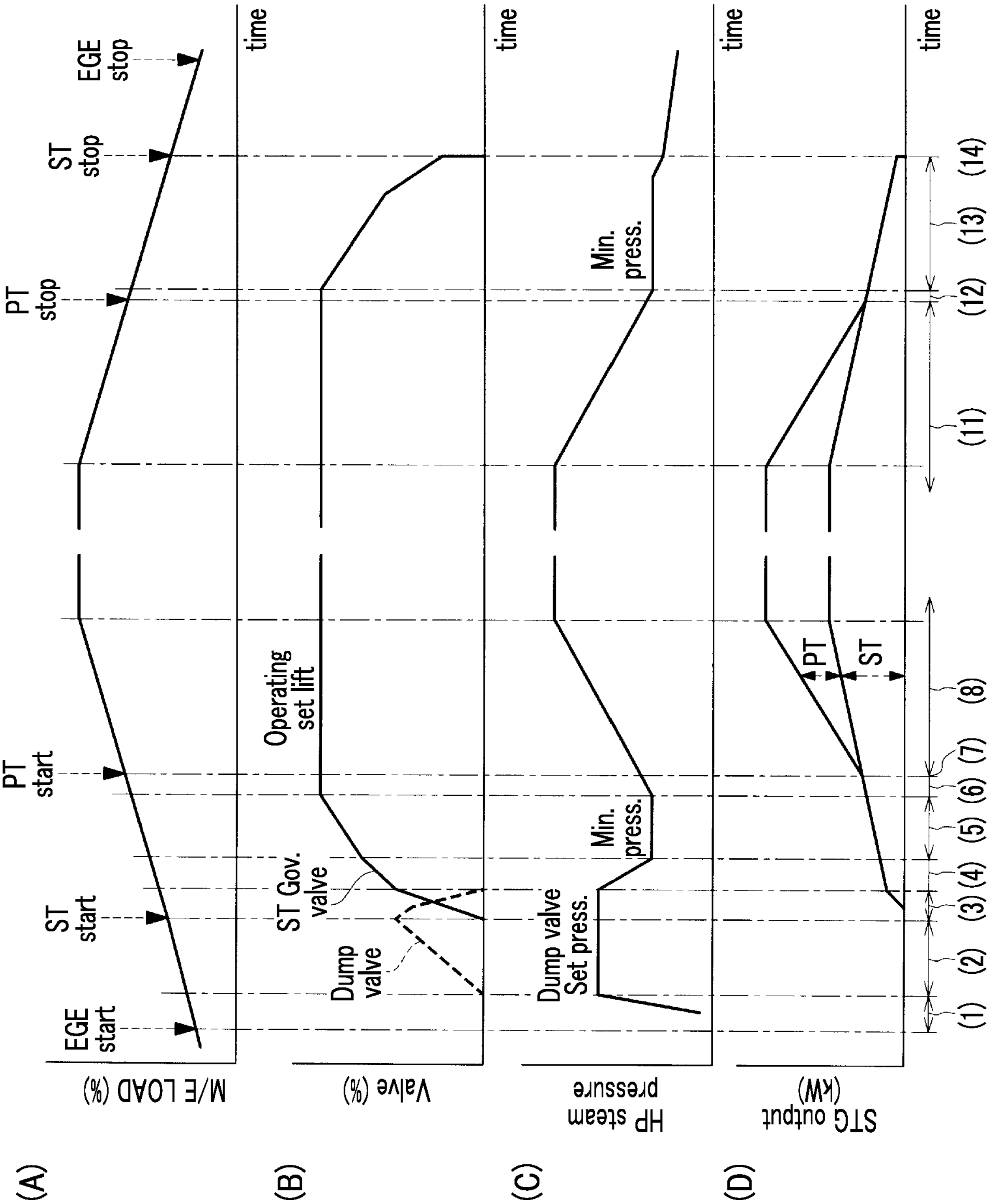
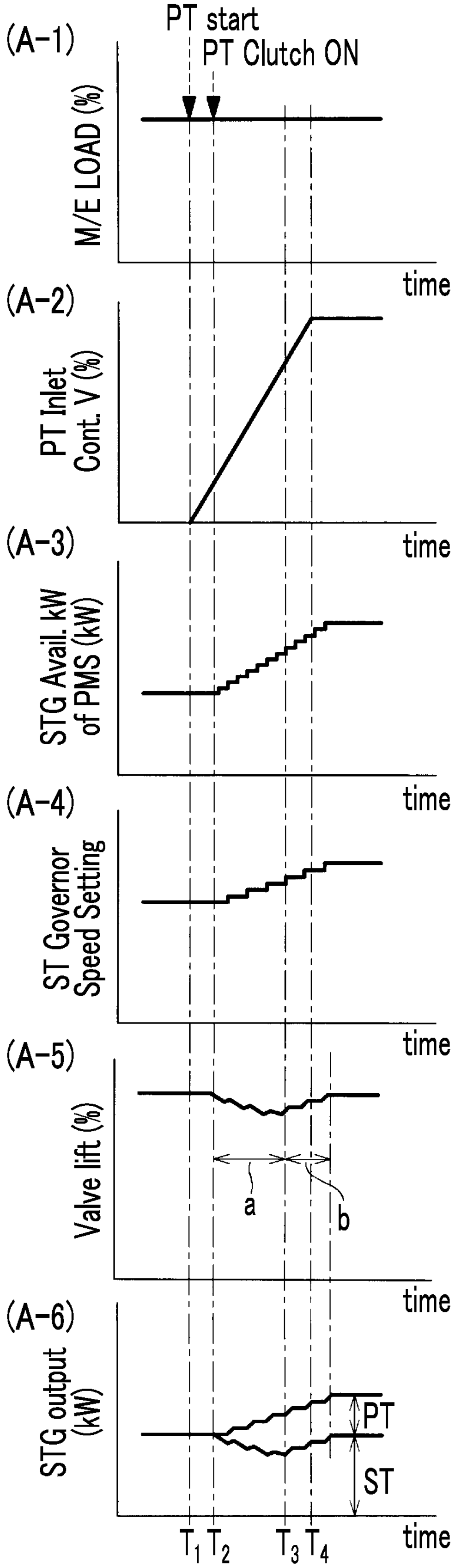

(A)
M/E LOAD (%)
EGE start
ST start
PT start
PT stop
ST stop
EGE stop
time
(B)
Valve (%)
Dump valve
ST Gov. valve
Operating set lift
time
(C)
HP steam pressure
Dump valve Set press.
Min. press.
Min. press.
time
(D)
STG output (kW)
PT
ST
time
(1)
(2)
(3)
(4)
(5)
(6)
(7)
(8)
(11)
(12)
(13)
(14)

FIG. 6A



(A-1)
PT start
PT Clutch ON
M/E LOAD (%)
time
(A-2)
PT Inlet Cont. V (%)
time
(A-3)
STG Avail. kW of PMS (kW)
time
(A-4)
ST Governor Speed Setting
time
(A-5)
Valve lift (%)
a
b
time
(A-6)
STG output (kW)
PT
ST
T1 T2 T3 T4
time

FIG. 6B

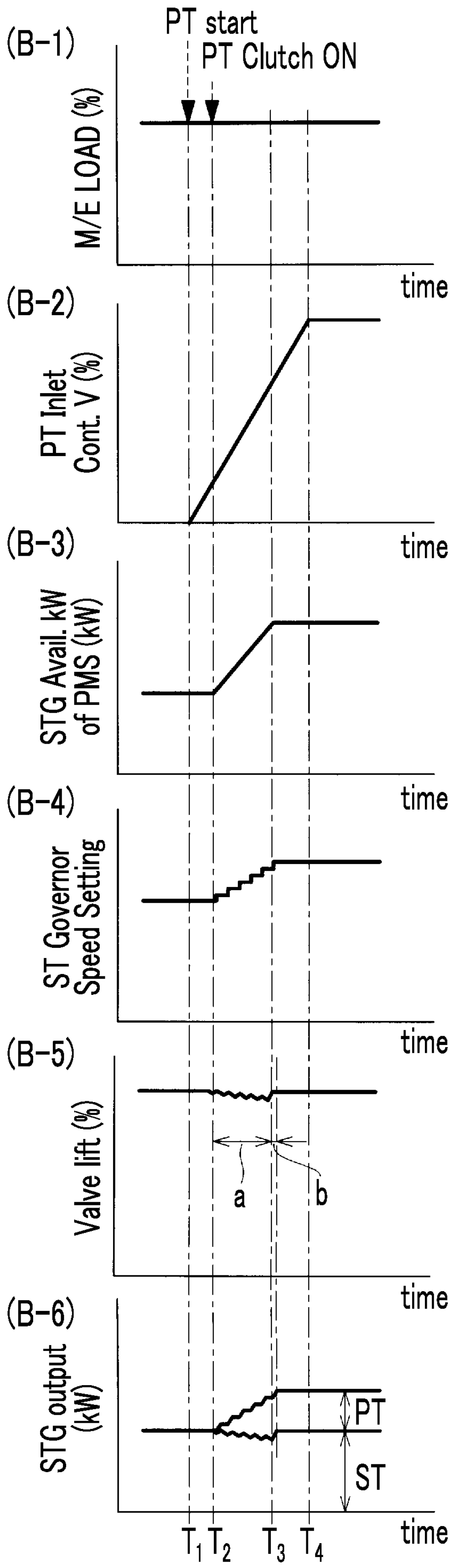
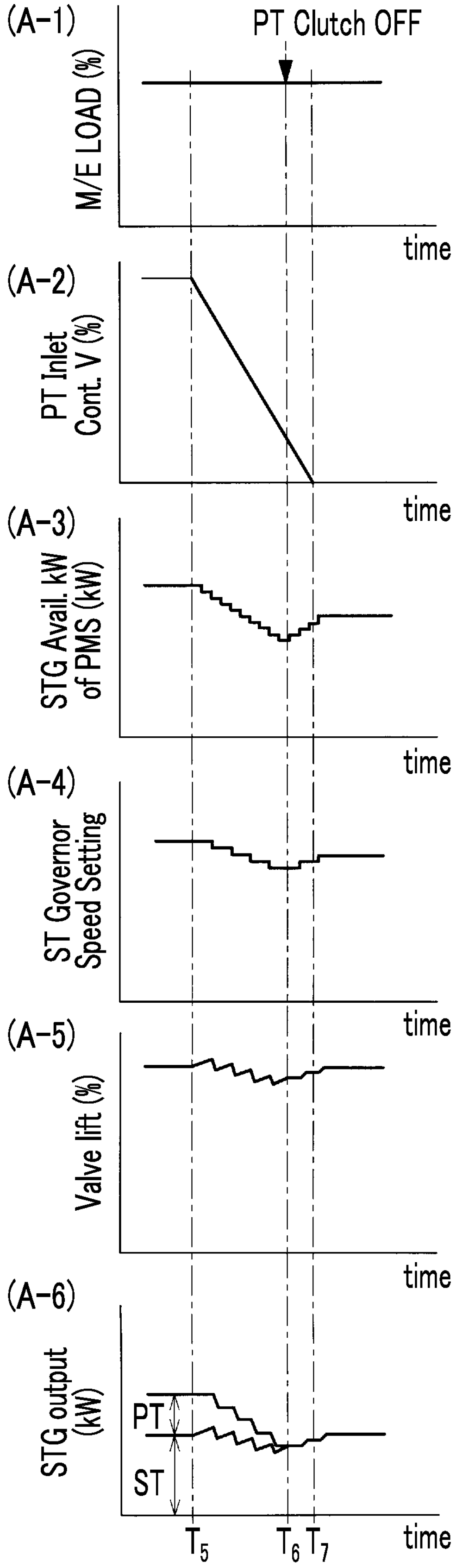

(B-1)
PT start
PT Clutch ON
M/E LOAD (%)
time
(B-2)
PT Inlet Cont. V (%)
time
(B-3)
STG Avail. kW of PMS (kW)
time
(B-4)
ST Governor Speed Setting
time
(B-5)
Valve lift (%)
a
b
time
(B-6)
STG output (kW)
PT
ST
T1 T2 T3 T4
time

FIG. 7A



(A-1)
PT Clutch OFF
M/E LOAD (%)
time
(A-2)
PT Inlet Cont. V (%)
time
(A-3)
STG Avail. kW of PMS (kW)
time
(A-4)
ST Governor Speed Setting
time
(A-5)
Valve lift (%)
time
(A-6)
STG output (kW)
PT
ST
T5
T6
T7
time

FIG. 7B

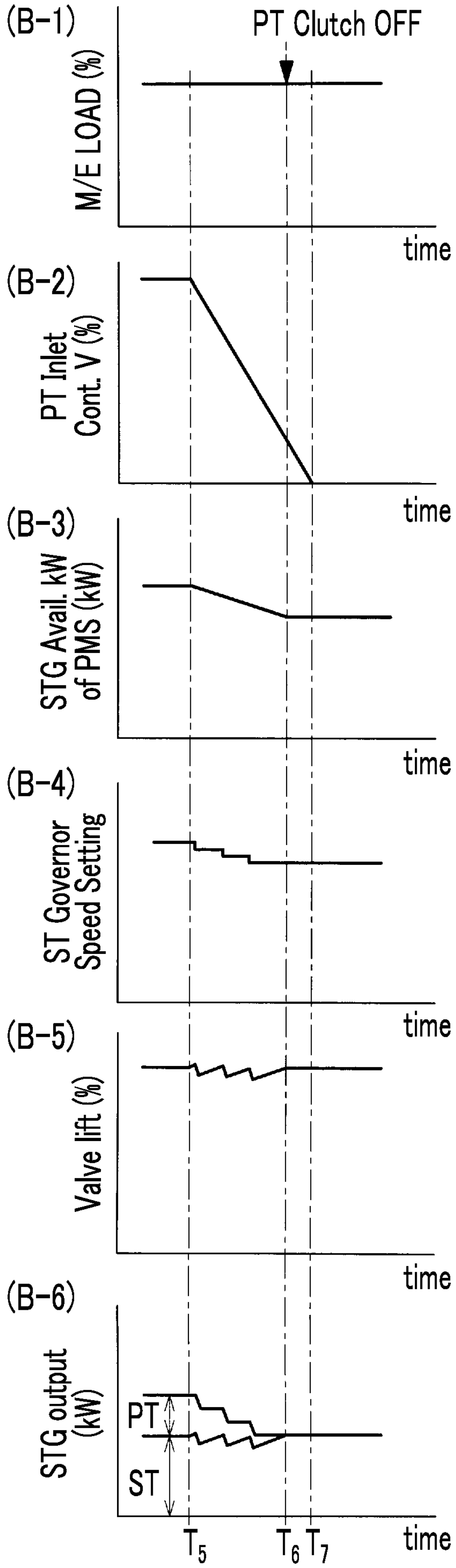

(B-1)
PT Clutch OFF
M/E LOAD (%)
time
(B-2)
PT Inlet Cont. V (%)
time
(B-3)
STG Avail. kW of PMS (kW)
time
(B-4)
ST Governor Speed Setting
time
(B-5)
Valve lift (%)
time
(B-6)
STG output (kW)
PT
ST
T5
T6
T7
time

FIG. 8A

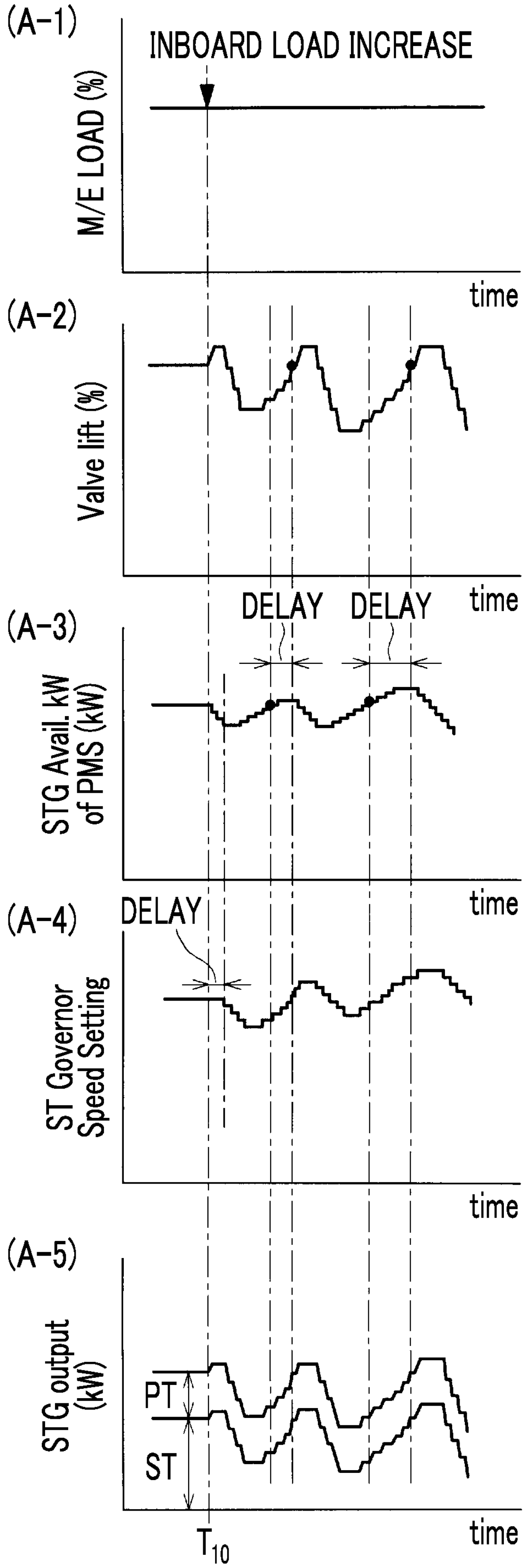

(A-1)
INBOARD LOAD INCREASE
M/E LOAD (%)
time
(A-2)
Valve lift (%)
time
(A-3)
DELAY
DELAY
STG Avail. kW of PMS (kW)
time
(A-4)
DELAY
ST Governor Speed Setting
time
(A-5)
STG output (kW)
PT
ST
T10
time

FIG. 8B

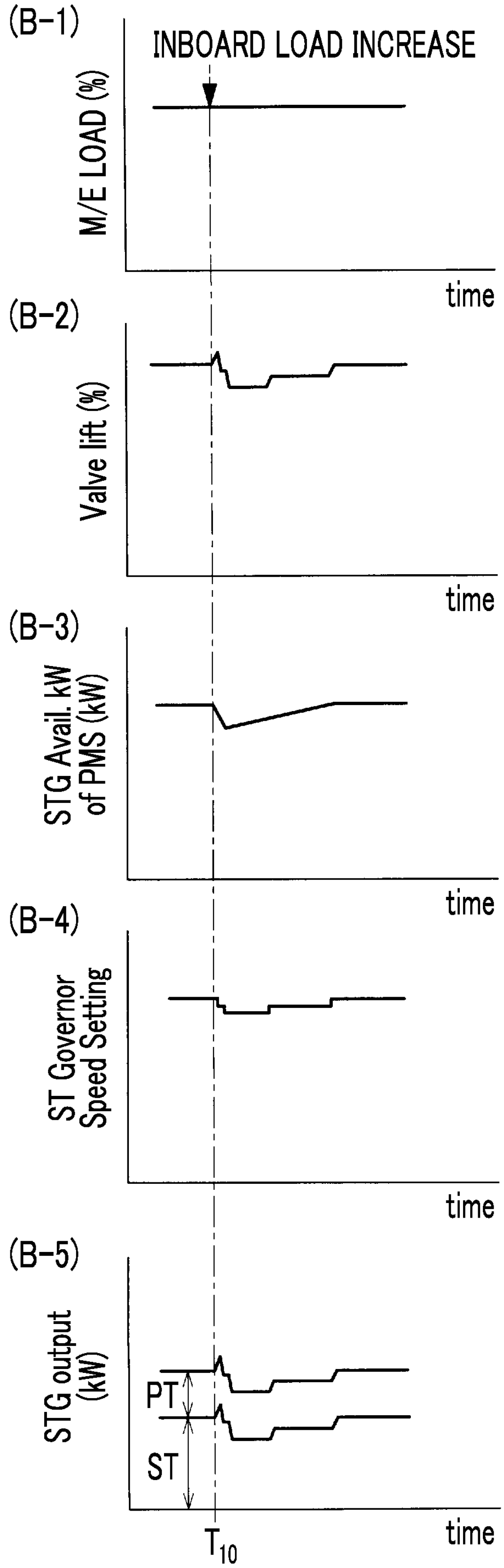
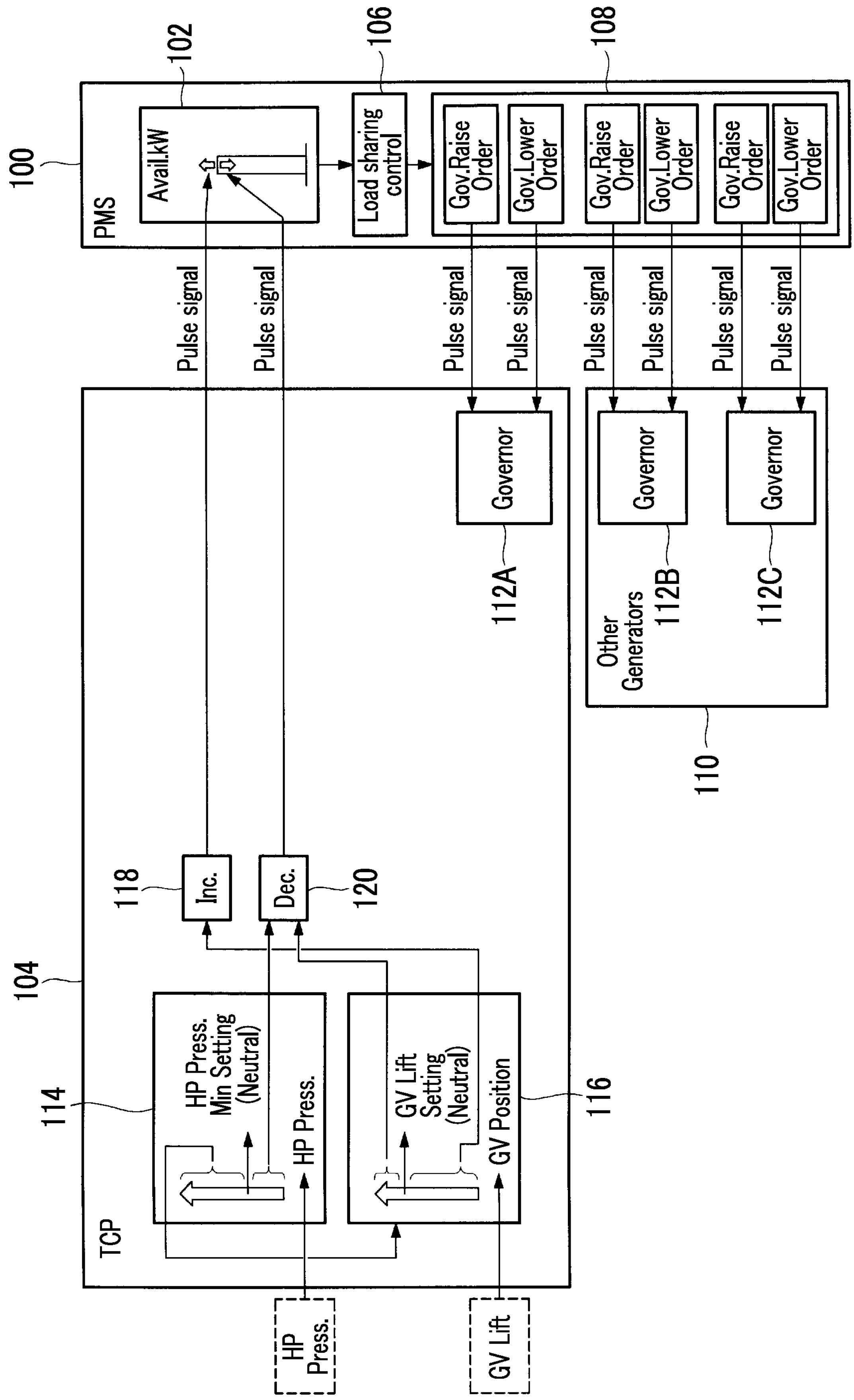

(B-1)
INBOARD LOAD INCREASE
M/E LOAD (%)
time
(B-2)
Valve lift (%)
time
(B-3)
STG Avail. kW of PMS (kW)
time
(B-4)
ST Governor Speed Setting
time
(B-5)
STG output (kW)
PT
ST
T_{10}
time

FIG. 9


100
PMS
102
Avail.kW
106
Load sharing control
108
Gov.Raise Order
Gov.Lower Order
Gov.Raise Order
Gov.Lower Order
Gov.Raise Order
Gov.Lower Order
Pulse signal
Pulse signal
Pulse signal
Pulse signal
Pulse signal
Pulse signal
Pulse signal
Pulse signal
104
TCP
114
HP Press. Min Setting (Neutral)
HP Press.
116
GV Lift Setting (Neutral)
GV Position
118
Inc.
120
Dec.
Governor
112A
Governor
112B
Governor
112C
Other Generators
110
HP Press.
GV Lift

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2016/073151

A. CLASSIFICATION OF SUBJECT MATTER
F01D17/24(2006.01)i, *F01D17/04*(2006.01)i, *F01D17/20*(2006.01)i, *F01K23/10* (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)
F01D17/24, F01D17/04, F01D17/20, F01K23/10

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

Jitsuyo Shinan Koho	1922-1996	Jitsuyo Shinan Toroku Koho	1996-2016
Kokai Jitsuyo Shinan Koho	1971-2016	Toroku Jitsuyo Shinan Koho	1994-2016

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.
Y A	JP 55-93906 A (Hitachi, Ltd.), 16 July 1980 (16.07.1980), claim 1; page 1, lower right column, line 12 to page 3, line 4; fig. 1 to 4 (Family: none)	1-2,4-9 3
Y A	JP 2013-29111 A (Mitsubishi Heavy Industries, Ltd.), 07 February 2013 (07.02.2013), paragraphs [0023] to [0028]; fig. 1 to 6 (Family: none)	1-2,4-9 3
A	JP 58-18506 A (Hitachi, Ltd.), 03 February 1983 (03.02.1983), page 2, upper left column, line 9 to page 3, upper right column, line 18; fig. 2, 5 to 6 (Family: none)	1-9

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

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"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
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
28 September 2016 (28.09.16)	11 October 2016 (11.10.16)

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

Form PCT/ISA/210 (second sheet) (January 2015)

REFERENCES CITED IN THE DESCRIPTION

Patent documents cited in the description

- JP 5155977 B **[0004]**