

DESCRIPTION

POWER GENERATION SYSTEM FOR SHIP AND POWER GENERATION METHOD
FOR POWER GENERATION SYSTEM FOR SHIP

Technical Field

[0001]

The present invention relates to a power generation system for a ship and a power generation method for a power generation system for a ship.

Background Art

[0002]

Ships using a propulsion engine have been conventionally known to apply a system that generates steam by heat recovery from flue gas discharged from the propulsion engine, and that introduces the steam into a steam turbine or the like.

Examples of the ships as described above include the ship as disclosed in Patent Citation 1.

Patent Citation 1 discloses a flue gas heat recovery device for a shipboard prime mover, which is configured to use an auxiliary boiler drum to also serve as a high-pressure steam separator in order to deliver steam from the high-pressure steam separator to a steam turbine.

[0003]

Patent Citation 1: Japanese Unexamined Patent
Application, Publication No. Sho57-49704

Disclosure of Invention

Technical Problem

[0004]

Meanwhile, employment of a gas turbine combined cycle (GTCC) in ships, which is a power generation system having high power generation efficiency, has been studied in recent years. However, the GTCC needs to install various devices such as a steam turbine, a flue gas economizer, and a steam separator. This leads to a problem of how to secure a space for installing these devices within the limited space of the ship.

In addition to power generation using combustion gas in a gas turbine, the GTCC generates power by generating steam by heat recovery from flue gas discharged from the gas turbine, and introducing this steam into the steam turbine. However, when the gas turbine is stopped during maintenance or due to other reasons, flue gas is not generated from the gas turbine. Thus, heat recovery cannot be performed, and accordingly steam cannot be generated. Consequently, there is a problem in that when the gas turbine is stopped, this prevents not only power generation by the gas turbine, but also power generation by

the steam turbine. In a case where the load of the gas turbine is reduced due to a problem with the gas turbine or other reasons, the amount of heat of flue gas generated from the gas turbine is also decreased. With this decrease, the amount of heat that can be recovered from flue gas is decreased. This causes an insufficient amount of steam to be generated and an insufficient steam temperature. Consequently, there is a problem in that as the load of the gas turbine is reduced, the amount of power generated by the steam turbine is reduced accordingly, which results in a significant reduction in the amount of power generated in the entire power generation system.

[0005]

The present invention has been made in view of the above circumstances, and a first object of the present invention is to provide a power generation system for a ship which can achieve space saving when a power generation system is introduced into a ship, and a power generation method for the power generation system for a ship.

A second object of the present invention is to provide a power generation system for a ship which can drive a steam turbine optimally regardless of an operational state of a gas turbine, which can improve the capacity utilization rate of the power generation system in its entirety, and which can satisfy the amount of power needed for a ship, and is also to

provide a power generation method for the power generation system for a ship.

Solution to Problem

[0006]

In order to solve the above problems, a power generation system for a ship, and a power generation method for a power generation system for a ship according to the present invention employ the following solutions.

A power generation system for a ship according to one aspect of the present invention comprises: a gas turbine that is driven by combustion gas; a first generator that is driven by the gas turbine and generates power; a flue gas economizer that generates steam by recovering heat from flue gas discharged from the gas turbine; a boiler including a furnace and a steam drum; a circulation flow path that is connected so as to use the steam drum as a steam separator for the flue gas economizer; a steam turbine that is driven by steam from the steam drum; and a second generator that is driven by the steam turbine and generates power.

[0007]

In the above configuration, the gas turbine outputs a rotational force and drives the first generator to generate power. The flue gas economizer recovers heat from flue gas discharged from the gas turbine. Steam generated by the flue

gas economizer is directed to the steam drum in the boiler through the circulation flow path. The steam drum is used as a steam separator to separate steam from water. The water separated from the steam in the steam drum is returned to the flue gas economizer through the circulation flow path. In contrast, the steam separated from the water in the steam drum is directed to the steam turbine to drive the steam turbine. When the steam turbine is driven by the steam, the second generator performs power generation. The power generation system for a ship configured as described above performs power generation in this manner.

Meanwhile, a plurality of boilers are installed in a ship and are used to generate steam needed for inboard chores and the like during traveling and in harbor. As a result of intensive studies to solve the above problems, the present inventors have focused attention on these boilers. When a steam drum of such a boiler is used as a steam separator for a flue gas economizer, then steam and water can be separated from each other without using an additional steam separator. Therefore, in a case where this boiler is used as a steam separator for the flue gas economizer, it is unnecessary to additionally install a steam separator intended for the flue gas economizer. This can reduce costs for additionally installing a steam separator, and can achieve space saving. The boiler described herein as being used as a steam separator

may be a boiler to be additionally provided, or may be a boiler having been already provided.

Flue gas generated from the boiler is used as inert gas. This eliminates the need for additionally installing a device that generates inert gas, and thus can reduce costs for additionally installing the device that generates inert gas, and can achieve space saving.

For example, if VOC or other non-hypergolic gas with a low-heat value is generated, mixed combustion of the gas with oil is performed in the boiler, so that the gas can also be properly combusted. Properly combusting non-hypergolic gas with a low-heat value can improve the energy efficiency in the power generation system for a ship in its entirety. Discharged gas, which can possibly affect the environments, is combusted in the boiler and can thereby be made harmless.

Note that, the first generator and the second generator may be integrated into a single generator.

A flue gas economizer may be provided between the steam drum and the steam turbine such that the flue gas economizer superheats steam to be supplied from the steam drum to the steam turbine. The flue gas economizer that generates steam may also be used to serve as the flue gas economizer provided between the steam drum and the steam turbine, or a flue gas economizer may be additionally provided between the steam drum and the steam turbine.

[0008]

The power generation system for a ship according to one aspect of the present invention may comprise a control unit that controls a burner provided in the furnace, wherein the control unit may have, as an operation mode of the boiler, a boiler operation mode of igniting the burner in accordance with a load of the gas turbine.

[0009]

In the above configuration, the control unit has a boiler operation mode of activating the burner provided in the furnace in accordance with a load of the gas turbine. The boiler is operated in this boiler operation mode, for example, in a case where a load of the gas turbine is lower than a predetermined value and thus the flue gas economizer cannot sufficiently generate steam. Because of this mode, the burner provided in the furnace is ignited to generate and heat steam in the boiler, so that steam can be sufficiently supplied to the steam turbine. With this operation, the steam turbine can compensate for a reduction in the amount of power generated by the gas turbine, the reduction being caused by a decrease in load of the gas turbine. Therefore, it becomes possible to stabilize power generation in the power generation system for a ship in its entirety. Thus, the power generation system for a ship can optimally satisfy the power needs for a ship.

For example, even though the gas turbine is stopped

during maintenance of the gas turbine or due to other reasons, power generation can still be performed using steam generated by the boiler. Therefore, non-operating time in the power generation system for a ship can be reduced.

[0010]

The power generation system for a ship according to one aspect of the present invention may comprise a control unit that controls a burner provided in the furnace, wherein the control unit may have, as an operation mode of the boiler, a boiler operation mode of igniting the burner during rated operation of the gas turbine.

[0011]

In the above configuration, the control unit has an operation mode of igniting the burner provided in the furnace during the rated operation of the gas turbine. Therefore, even though the amount of power needed is further increased when the gas turbine is in a rated-operation state, the boiler is activated to further heat steam generated by the flue gas economizer and then the heated steam can be supplied to the steam turbine. Accordingly, the steam turbine can generate an increased amount of power, which can satisfy the increased power needs.

[0012]

The power generation system for a ship according to one aspect of the present invention may comprise a control unit

that has, as an operation mode, a first operation mode in which only the second generator performs power generation by stopping the gas turbine to ignite a burner provided in the furnace, and introducing steam from the steam drum into the steam turbine, and a second operation mode in which the first generator and the second generator perform power generation by driving the gas turbine, and introducing steam generated by the flue gas economizer from the steam drum to the steam turbine, wherein the control unit may select the operation mode in accordance with power needs for a ship.

[0013]

In the above configuration, the operation mode is selected in accordance with the amount of power needed for a ship. With this selection, power can be generated in accordance with the amount of power needed for a ship.

For example, in a case of a relatively small amount of power needed for a ship, it is considered that the power generation system for a ship is operated in the first operation mode. In the case of a relatively small amount of power needed for a ship, it is difficult for a gas turbine that generates a large amount of power to meet the needs. There is thus a possibility that the gas turbine generates an excess amount of power or performs power generation in an operation state with very low power generation efficiency. However, when the power generation system for a ship is

operated in the first operation mode, the power generation system for a ship performs power generation only using steam generated by the boiler. This makes it possible to generate a smaller amount of power than the minimum amount of power generated by the gas turbine, and thus can meet the need for a small amount of power. Therefore, the power generation system for a ship can generate power in accordance with the amount of power needed. Because the power generation system for a ship can cover a wider range of the amount of power needed in the manner as described above, the power generation efficiency in the power generation system for a ship in its entirety can be improved.

For example, in a case of a relatively large amount of power needed for a ship, it is considered that the power generation system for a ship is operated in the second operation mode. In the case of a relatively large amount of power needed for a ship, the first generator performs power generation using a drive force of the gas turbine, while the second generator performs power generation using steam generated by the flue gas economizer. Therefore, the power generation system for a ship can generate power in accordance with the amount of power needed.

In the manner as described above, based on the amount of power needed, a more efficient operation mode for generating this amount of power needed can be selected from either the

first operation mode or the second operation mode. This can improve the power generation efficiency in the power generation system for a ship in its entirety.

[0014]

In the power generation system for a ship according to one aspect of the present invention, the control unit may have, as the operation mode, a third operation mode in which the first generator and the second generator perform power generation by igniting the burner provided in the furnace, and introducing steam from the steam drum into the steam turbine.

[0015]

In the above configuration, the control unit has, as the operation mode, the third operation mode of introducing steam from the steam drum through the flue gas economizer and the furnace in the boiler into the steam turbine. With this configuration, for example, even in a case where the amount of power needed for a ship exceeds the amount of power that can be generated during the rated operation of the gas turbine, the amount of power to be generated by the steam turbine can be increased by activating the boiler. Thus, power can be generated in accordance with the amount of power needed. In this manner, a larger amount of power can be generated than the amount of power that can be generated during the rated operation of the gas turbine. Consequently, a downsized gas turbine can be provided compared to the gas turbine that meets

the maximum power generation amount estimated for the power generation system for a ship. This can reduce costs for installing the gas turbine.

[0016]

The power generation system for a ship according to one aspect of the present invention may comprise a boiler flue gas pipe through which flue gas is directed from the boiler to the flue gas economizer.

[0017]

In the above configuration, because flue gas from the boiler is also introduced into the flue gas economizer, heat can also be recovered from the flue gas discharged from the boiler. The flue gas economizer for the gas turbine is used to perform heat recovery from flue gas from the boiler. A flue gas economizer for the boiler is not additionally installed. This can reduce costs for additionally installing a flue gas economizer for the boiler, and thus can achieve space saving.

[0018]

The power generation system for a ship according to one aspect of the present invention may comprise: a flue gas economizer for a boiler that heats steam by recovering heat from flue gas discharged from the boiler; and a boiler flue gas pipe through which flue gas discharged from the boiler is directed to the flue gas economizer for a boiler.

[0019]

In the above configuration, because flue gas from the boiler is also introduced into the flue gas economizer for a boiler, heat can also be recovered from the flue gas discharged from the boiler. The flue gas economizer for the gas turbine is provided separately from the flue gas economizer for a boiler. Thus, for example, even when the boiler and the gas turbine are operated simultaneously, heat recovery can still be performed without mixing flue gas discharged from the gas turbine with flue gas discharged from the boiler.

[0020]

A power generation method for a power generation system for a ship according to one aspect of the present invention comprises: a gas turbine driving step of driving a gas turbine by combustion gas; a first power generating step of generating power by a first generator driven by the gas turbine; a heat recovering step of recovering heat from flue gas discharged from the gas turbine; a steam separating step of separating steam from water, the steam being obtained in the heat recovering step by a steam drum in a boiler including a furnace and the steam drum; a steam turbine driving step of driving a steam turbine by steam obtained in the steam separating step; and a second power generating step of generating power by a second generator driven by the steam

turbine.

Advantageous Effects of Invention

[0021]

The present invention can achieve space saving when the power generation system is introduced into a ship.

Further, the present invention improves the capacity utilization rate in the power generation system for a ship in its entirety, and can optimally satisfy the power needs for a ship.

Brief Description of Drawings

[0022]

[FIG. 1] FIG. 1 is a schematic configuration diagram showing a power generation system for a ship according to a first embodiment of the present invention.

[FIG. 2] FIG. 2 is a graph showing an example of a load distribution in the power generation system for a ship shown in FIG. 1.

[FIG. 3] FIG. 3 is a graph showing an example of a load distribution in the power generation system for a ship shown in FIG. 1.

[FIG. 4] FIG. 4 is a schematic configuration diagram showing a power generation system for a ship according to a second embodiment of the present invention.

[FIG. 5] FIG. 5 is a table showing a valve opened/closed state in each operation mode of the power generation system for a ship shown in FIG. 4.

[FIG. 6] FIG. 6 is a graph showing a relationship between efficiency in the power generation system for a ship shown in FIG. 4 and a plant load.

[FIG. 7] FIG. 7 is a schematic configuration diagram showing a power generation system for a ship according to a third embodiment of the present invention.

[FIG. 8] FIG. 8 is a schematic configuration diagram showing a modification of the power generation system for a ship shown in FIG. 7.

Best Mode for Carrying Out the Invention

[0023]

Embodiments of the power generation system for a ship according to the present invention are described below with reference to the diagrams.

[0024]

First Embodiment

A first embodiment of the present invention is described below with reference to FIG. 1.

As shown in FIG. 1, a power generation plant (power generation system for a ship) 1 installed in a ship, for example, an LNG ship, is a so-called gas turbine combined

cycle (GTCC). The power generation plant 1 includes a gas turbine 2, a flue gas economizer 3 that recovers heat from flue gas discharged from the gas turbine 2, a boiler 4, a steam turbine 5 that is driven by steam from the boiler 4, and a control unit 6 that controls the boiler 4 and other devices.

[0025]

The gas turbine 2 generates rotational power by combusting flue in a combustor (not shown) and supplying combustion gas to the turbine, and discharges high-temperature flue gas. The flue gas discharged from the gas turbine 2 flows through a flue gas pipe 11, and is directed to the flue gas economizer 3 as shown by the arrow in FIG. 1. A rotational shaft of a first generator 14 is connected to a rotational shaft of the gas turbine 2. The first generator 14 generates electric power using a rotational force of the gas turbine 2. The electric power generated by the first generator 14 is supplied to the inboard system and used as power for the main unit of the ship and as inboard electric power.

[0026]

In the flue gas economizer 3, a superheater 12 and a steam generator 13 are located in a direction of the flue gas flow from the upstream side toward the downstream side. The superheater 12 and the steam generator 13 are installed within a flue in the described order from the bottom toward the top,

and are a bank of heat transfer tubes. High-temperature flue gas directed from the gas turbine 2 flows within the flue. After having flowed within the flue, the flue gas is discharged to the atmosphere via a stack (not shown) connected to the downstream side of the flue gas economizer 3.

[0027]

The boiler 4 includes a furnace 16, a steam drum 17 located on the upper side, and a water drum 18 located on the lower side. A heat transfer tube (not shown) is provided within the furnace 16 and is located between the steam drum 17 and the water drum 18. The furnace 16 includes a burner 19 and performs combustion within the furnace 16. In the boiler 4, a boiler superheater 23 is provided. Flue is supplied from a flue supply unit 20 through a flue supply tube 21 to the burner 19. The flue supply tube 21 is provided with a flue supply valve 22. The flue supply valve 22 is opened or closed to supply flue or stop the flue supply. The valve opening of the flue supply valve 22 is controlled by the control unit 6.

When the burner 19 is ignited in the furnace 16, feedwater is heated in the boiler 4. Then, the water flows upward from the water drum 18 on the lower side toward the steam drum 17 on the upper side. Vapor and liquid are separated from each other in the steam drum 17. As described above, the boiler 4 originally serves as a natural circulation type boiler. However, in a case where the boiler 4 is used as

a steam separator for the flue gas economizer 3, the boiler 4 is not supposed to be used as a natural circulation type boiler. A circulating water pipe 26, through which water is fed to the upstream end portion of the steam generator 13, is connected to the steam drum 17. The circulating water pipe 26 is provided with a circulating water pump 27. The circulating water pump 27 is activated or stopped in accordance with a command from the control unit 6. A steam-water mixture pipe 28 is provided between the downstream end portion of the steam generator 13 and the steam drum 17. The circulating water pipe 26 and the steam-water mixture pipe 28, which are described above, form a circulation flow path 29 through which water and steam circulate between the steam drum 17 and the steam generator 13.

[0028]

Steam after having been separated from water by the steam drum 17 passes through a steam output pipe 31, and is supplied to the superheater 12 provided in the flue gas economizer 3. The steam supplied to the superheater 12 is superheated and then introduced into the steam turbine 5 through a steam turbine input tube 30.

[0029]

The steam output pipe 31 is provided with a steam output pipe valve 32. A first boiler superheating pipe 33 branches off the steam output pipe 31 from a position somewhere on the

upstream side relative to the steam output pipe valve 32. The downstream end of the first boiler superheating pipe 33 is connected to the upstream end of the boiler superheater 23 provided within the furnace 16. The downstream end of the boiler superheater 23 is connected to the upstream end of a second boiler superheating pipe 34. The downstream end of the second boiler superheating pipe 34 is connected to the steam output pipe 31 at a position somewhere on the downstream side relative to the steam output pipe valve 32. The second boiler superheating pipe 34 is provided with a boiler superheating valve 35.

[0030]

The steam turbine 5 is driven by steam supplied from the boiler 4. A rotational shaft of a second generator 37 is connected to a rotational shaft of the steam turbine 5. The second generator 37 generates electric power using a rotational force of the steam turbine 5. The electric power generated by the second generator 37 is supplied to the inboard system and used as power for the main unit of the ship and as inboard electric power. There are cases where steam to be supplied from the boiler 4 to the steam turbine 5 is generated by heating water and the like in the boiler 4, and where steam to be supplied from the boiler 4 to the steam turbine 5 is generated by separating steam, generated in the flue gas economizer 3, from water by the boiler 4.

A steam condenser 38 is provided below the steam turbine 5. In the steam condenser 38, steam having passed through the steam turbine 5 condenses, which generates water. The water generated is collected as condensate.

[0031]

In accordance with an operation status of the gas turbine 2, the control unit 6 switches between using the boiler 4 as an original natural circulation type boiler and stopping the operation of the boiler 4 as a natural circulation type boiler, instead using the steam drum 17 as a steam separator for the steam generator 13. The control unit 6 is made up of, for example, a Central Processing Unit (CPU), a Random Access Memory (RAM), a Read Only Memory (ROM), and a computer-readable storage medium or the like. As an example, a series of processes to implement various types of functions are stored in the storage medium or the like in the form of a program. The CPU reads this program in the RAM or the like and performs information processing and computation to thereby implement various types of functions. Note that, it may be applicable to install a program in advance in the ROM or other storage media, or to provide a program stored in a computer-readable storage medium, or to distribute a program through a wired or wireless communication means. The computer-readable storage medium refers to a magnetic disk, a magneto-optical disk, a CD-ROM, a DVD-ROM, a semiconductor memory, or the

like.

[0032]

Next, operation of the power generation plant 1 configured as described above is explained.

Normal Operation

During normal operation of the gas turbine 2, that is, during the rated operation, only power generation by the gas turbine 2 and power generation by the steam turbine 5 driven by steam generated by the flue gas economizer 3 satisfy the amount of power needed for the power generation plant 1 as shown in the graph in FIG. 2. It is thus unnecessary to generate steam in the boiler 4. Therefore, ignition of the burner 19 in the boiler 4 is stopped in accordance with a command from the control unit 6.

As mentioned above, during normal operation of the gas turbine 2, it is possible to generate steam in the flue gas economizer 3. In this case, in accordance with a command from the control unit 6, the steam drum 17 in the boiler 4 is switched to being used as a steam separator for the steam generator 13. Specifically, water is fed from a feedwater pipe (not shown) to the steam drum 17, and the circulating water pump 27 is activated. With this operation, steam is generated in the steam generator 13, the steam and water are separated from each other in the steam drum 17, and then the steam is delivered to the superheater 12. In the present

embodiment, as shown in FIG. 2, during normal operation, the ratio between the amount of power generated by the gas turbine 2 and the amount of power generated by the steam turbine 5 driven by steam generated by the flue gas economizer 3 is expressed as 70% to 30%. However, these numerical values are merely an example. Another ratio may also be set between the amount of power generated by the gas turbine 2 and the amount of power generated by the steam turbine 5 driven by steam generated by the flue gas economizer 3.

[0033]

Limited Gas Turbine Load

In a case where the load of the gas turbine 2 is limited compared to the rated operation due to a problem with the gas turbine 2 or other reasons, the heating value of flue gas discharged from the gas turbine 2 is also limited, and accordingly the function of generating steam in the flue gas economizer 3 also declines. Specifically, as shown in FIG. 2, in a case where the load of the gas turbine 2 is reduced compared to the normal operation, the amount of power generated by the gas turbine 2 is also decreased. With this decrease, the amount of power generated by the steam turbine 5 driven by steam generated by the flue gas economizer 3 is also decreased. At this time, in accordance with a command from the control unit 6, the boiler 4 is controlled so as to operate as a natural circulation type boiler in such a manner

as to compensate for the decreased amount of power generated. Specifically, the burner 19 in the boiler 4 is ignited, and feedwater is heated in the furnace 16 to generate steam. In the case where the load of the gas turbine 2 is limited compared to the rated operation due to a problem with the gas turbine 2 or other reasons, steam is not optimally superheated in the flue gas economizer 3. For this reason, when it is desired to optimally superheat steam to improve the power generation efficiency, the steam output pipe valve 32 may be brought into a closed state, while the boiler superheating valve 35 may be brought into an opened state. The control unit 6 controls these valves in the manner as described above so that steam from the steam drum 17 is superheated by the boiler superheater 23 within the furnace 16, and thereby the power generation efficiency can be improved. In the present embodiment, as shown in FIG. 2, when the load of the gas turbine 2 is limited, the ratio between the amount of power generated by the gas turbine 2, the amount of power generated by the steam turbine 5 driven by steam generated by the flue gas economizer 3, and the amount of power generated by the steam turbine 5 driven by steam generated by the boiler 4 is expressed as 60% to 20% to 20%, respectively. These numerical values are merely an example. Another ratio may also be set as the ratio between the respective amounts of power generated.

[0034]

Stop of Gas Turbine

In a case where the gas turbine 2 is stopped during maintenance of the gas turbine 2 or due to other reasons, steam is not generated in the flue gas economizer 3. However, there may still be electric demand from a ship even during maintenance of the gas turbine 2 in some cases. Thus, in accordance with a command from the control unit 6, the boiler 4 is controlled so as to operate as a natural circulation type boiler. Specifically, the burner 19 in the boiler 4 is ignited, and feedwater is heated in the furnace 16 to generate steam. In the case where the gas turbine 2 is stopped during maintenance of the gas turbine 2 or due to other reasons, steam is not superheated in the flue gas economizer 3. Thus, when it is desired to superheat steam to improve the power generation efficiency, the steam output pipe valve 32 may be brought into a closed state, while the boiler superheating valve 35 may be brought into an opened state. The control unit 6 controls these valves in the manner as described above so that steam from the steam drum 17 is superheated by the boiler superheater 23 within the furnace 16, and thereby the power generation efficiency can be improved.

[0035]

Increased Power Generation Plant Load

In a case where the amount of power needed for the power

generation plant 1 is further increased due to demand from a ship and the like compared to when the gas turbine 2 is in a rated-operation state (see FIG. 3), the boiler 4 is controlled so as to operate as a natural circulation type boiler in accordance with a command from the control unit 6 in such a manner as to satisfy the increased amount of power needed. Specifically, the burner 19 in the boiler 4 is ignited, and feedwater is heated in the furnace 16 to generate steam. In the present embodiment, as shown in Figure 3, when the power generation plant load is increased, the ratio between the amount of power generated by the gas turbine 2, the amount of power generated by the steam turbine 5 driven by steam generated by the flue gas economizer 3, and the amount of power generated by the steam turbine 5 driven by steam generated by the boiler 4 is expressed as 70% to 30% to 20%, respectively. These numerical values are merely an example. Another ratio may also be set as the ratio between the respective amounts of power generated.

[0036]

The present embodiment achieves the following operational effects.

In the present embodiment, the control unit 6 controls the burner 19 provided in the furnace 16 so as to activate or stop the burner 19 in accordance with a load of the gas turbine 2. With this control, although the load of the gas

turbine 2 is limited, the burner 19 provided in the furnace 16 is ignited to generate and heat steam in the boiler 4, so that steam can be sufficiently supplied to the steam turbine 5. Therefore, the steam turbine 5 can compensate for a reduction in the amount of power generated by the gas turbine 2, the reduction being caused by a decrease in load of the gas turbine 2. This makes it possible to stabilize power generation in the power generation plant 1 in its entirety. Thus, the power generation plant 1 can optimally satisfy the power needs for a ship.

For example, even though the gas turbine 2 is stopped during maintenance of the gas turbine 2 or due to other reasons, power generation can still be performed by the boiler 4. Therefore, non-operating time in the power generation plant 1 can be reduced.

Even though the amount of power needed is further increased when the gas turbine 2 is in a rated-operation state, the boiler 4 is activated to further heat steam generated by the flue gas economizer 3 and then the heated steam can be supplied to the steam turbine 5. As the flue gas economizer 3 generates an increased amount of steam, an increased amount of steam is supplied to the steam turbine 5. Accordingly, the steam turbine 5 generates an increased amount of power, which can satisfy the power needs that have arisen.

Flue gas generated from the boiler 4 is used as inert

gas. This eliminates the need for additionally installing a device that generates inert gas, and thus can reduce costs for additionally installing the device that generates inert gas, and can achieve space saving.

If VOC or other non-hypergolic gas with a low-heat value is generated, mixed combustion of the gas with oil is performed in the boiler 4, so that non-hypergolic gas with a low-heat value can also be properly combusted. Properly combusting non-hypergolic gas with a low-heat value can improve the energy efficiency in the power generation plant 1 in its entirety. Discharged gas, which can possibly affect the environments, is combusted in the boiler 4 and can thereby be made harmless.

In a case where an auxiliary boiler having been already provided in a ship is used as the boiler 4, it is unnecessary to additionally install a steam separator intended for the flue gas economizer 3. This can reduce costs for additionally installing a steam separator, and can achieve space saving. Note that, in a case where the auxiliary boiler is used, a part of the steam from the auxiliary boiler is delivered to the inboard location where there is demand (for example, to an oil heating device and the like).

[0037]

Second Embodiment

A second embodiment of the present invention is described

below with reference to FIG. 4.

The present embodiment basically has a structure identical to the first embodiment, except for the structure of a pipe connecting the steam drum 17 and the steam turbine 5. Therefore, like elements are denoted by like reference signs in the first and second embodiments and descriptions thereof are omitted.

As shown in FIG. 4, a steam output pipe 51 connecting the steam drum 17 and the superheater 12 is provided with a second valve B2 (note that, although the second valve B2 is located at the same position as the steam output pipe valve 32 according to the first embodiment, the second valve B2 is named differently and denoted by a different reference sign from the steam output pipe valve 32 because of a different usage). A steam turbine input tube 52 connecting the superheater 12 and the steam turbine 5 is provided with a third valve B3. A bypass pipe 53 branches off the steam output pipe 51 from the upstream side relative to the second valve B2. The bypass pipe 53 is provided with a first valve B1. The bypass pipe 53 connects to a connection point P1 at a position somewhere along the steam turbine input tube 52, the connection point P1 being positioned on the upstream side relative to the third valve B3. A branch point P2 is provided between the third valve and the connection point P1 on the steam turbine input tube 52. A boiler superheating tube 54

branches off from the branch point P2. The boiler superheating tube 54 is provided with the boiler superheater 23 located in the furnace 16 and a fourth valve B4 in the described order from the upstream side of the above flow. The downstream end of the boiler superheating tube 54 is connected at a position somewhere between the steam turbine 5 and the third valve B3 of the steam turbine input tube 52.

[0038]

Next, operation of the power generation plant 1 configured as described above is explained.

Power Generation Plant Low-Load Operation Mode (First Operation Mode)

Under a low load of the power generation plant 1, that is, when a small amount of power is needed for a ship, the control unit 6 stops the gas turbine 2, and also brings the first valve B1 and the fourth valve B4 into an opened state, while bringing the second valve B2 and the third valve B3 into a closed state, as shown in FIG. 5. Further, in accordance with a command from the control unit 6, the boiler 4 is controlled so as to operate as a natural circulation type boiler. Specifically, the burner 19 in the boiler 4 is ignited, and feedwater is heated in the furnace 16 to generate steam. The control unit 6 controls the boiler 4 in this manner, so that steam generated in the boiler 4 passes through the boiler superheater 23 within the boiler 4 and is

superheated, and then the superheated steam drives the steam turbine 5. In the manner as described above, power can be generated by operation of the boiler 4 alone.

[0039]

Power Generation Plant Intermediate-Load Operation Mode
(Second Operation Mode)

When the load of the power generation plant 1 is increased from the low load, that is, under a power generation plant intermediate load, the control unit 6 activates the gas turbine 2, and also brings the second valve B2 and the third valve B3 into an opened state, while bringing the first valve B1 and the fourth valve B4 into a closed state, as shown in FIG. 5. Further, in accordance with a command from the control unit 6, the boiler 4 is stopped to switch the steam drum 17 in the boiler 4 to being used as a steam separator for the steam generator 13. Specifically, ignition of the burner 19 in the boiler 4 is stopped, and water is fed from the feedwater pipe to the steam drum 17, while the circulating water pump 27 is activated.

[0040]

Power Generation Plant High-Load Operation Mode (Third Operation Mode)

Under a high load of the power generation plant 1, that is, when a ship needs the amount of power generated, which exceeds the total amount of power generated, that is, the sum

of the amount of power that can be generated during the rated operation of the gas turbine 2, and the amount of power that can be generated using steam generated by heat from the gas turbine, then the control unit 6 brings the second valve B2 and the fourth valve B4 into an opened state, while bringing the first valve B1 and the third valve B3 into a closed state, as shown in FIG. 5. Further, the control unit 6 activates the boiler 4 again and controls the boiler 4 so as to operate as a natural circulation type boiler. Specifically, the burner 19 in the boiler 4 is ignited, and feedwater is heated in the furnace 16 to generate steam and also superheat the steam to be introduced into the steam turbine 5.

[0041]

Next, switching between the aforementioned respective operation modes according to the present embodiment is described.

As shown in FIG. 6, a power generation plant low-load operation mode M1 is switched to a power generation plant intermediate-load operation mode M2 at a switching point A1. At the switching point A, the power generation efficiency in the intermediate-load operation mode becomes greater than the power generation efficiency in the low-load operation mode. In the present embodiment, the power generation plant low-load operation mode M1 is switched to the power generation plant intermediate-load operation mode M2 at the power generation

plant load of 25% as shown in FIG. 6. Note that, the switching point, at which the power generation plant low-load operation mode is switched to the power generation plant intermediate-load operation mode, may vary depending on the size of the gas turbine 2, the size of the steam turbine 5, the size of the boiler 4, steam conditions (steam pressure and steam temperature), and other conditions. The switching point may be set at a plant load other than 25%.

[0042]

The present embodiment achieves the following operational effects.

In the present embodiment, the operation mode is selected in accordance with the power generation plant load (the amount of power needed for a ship). With this selection, power can be generated in accordance with the amount of power needed for a ship.

Specifically, in a case of a relatively small amount of power needed for a ship, it is difficult for the gas turbine 2 that generates a large amount of power to meet the needs. There is thus a possibility that the gas turbine 2 generates an excess amount of power. If the amount of power generated is reduced to the amount of power needed, the operation is likely to become inefficient. However, when the power generation plant 1 is operated in the power generation plant low-load operation mode, power generation can be performed

only using steam generated by the boiler 4 which generates a smaller amount of power than the gas turbine 2. Thus, power can be generated in accordance with the amount of power needed. Even in a case where the amount of power needed for a ship exceeds the amount of power that can be generated during the rated operation of the gas turbine 2, when the power generation plant 1 is operated in the power generation plant high-load operation mode, then this can increase the amount of power to be generated by the steam turbine 5 by activating the boiler 4. Thus, power can be generated in accordance with the amount of power needed.

Because the power generation plant 1 can cover a wider range of the amount of power needed for a ship in the manner as described above, the power generation efficiency in the power generation plant 1 in its entirety can be improved.

[0043]

Third Embodiment

A third embodiment of the present invention is described below with reference to FIG. 7.

The present embodiment basically has a structure identical to the second embodiment, except for several additional elements. Therefore, like elements are denoted by like reference signs in the second and third embodiments and descriptions thereof are omitted.

As shown in FIG. 7, the power generation plant 1

according to the present embodiment includes a boiler flue gas pipe 61 through which flue gas from the boiler 4 is directed to the flue gas economizer 3. With this configuration, heat can also be recovered from flue gas from the boiler 4. The flue gas economizer 3 for the gas turbine 2 is used to perform heat recovery from flue gas from the boiler 4. A flue gas economizer for the boiler 4 is not additionally installed. This can reduce costs for additionally installing a flue gas economizer for the boiler 4, and thus can achieve space saving. Flue gas from the gas turbine 2 and flue gas from the boiler 4 are almost at equal temperature. Thus, the flue gas economizer 3 can be shared between the gas turbine 2 and the boiler 4 without providing the flue gas economizer 3 with a thermal resistant material or the like. Only flue gas flows through from the boiler 4 to the flue gas economizer 3 under a low load, while only flue gas flows through from the gas turbine 2 to the flue gas economizer 3 under an intermediate load. Therefore, even in the configuration in which the flue gas economizer is shared, flue gas from the gas turbine 2 is not mixed with flue gas from the boiler 4 under a low load and an intermediate load.

Note that, as shown in FIG. 8, a flue gas economizer 71 for a boiler may be provided at a position somewhere along the steam output pipe 51, and a flue gas pipe for boiler 72 may be provided so as to direct flue gas from the boiler 4 to the

flue gas economizer 71 for a boiler. With this configuration, even when the boiler 4 and the gas turbine 2 are operated simultaneously, heat recovery can still be performed without mixing flue gas discharged from the gas turbine 2 with flue gas discharged from the boiler 4.

[0044]

The present invention is not limited to the inventions according to the above embodiments, and changes and modifications may be optionally made without departing from the scope of the present invention. For example, in the above embodiments, a generator driven by a rotational force of the gas turbine 2, and a generator driven by a rotational force of the steam turbine 5 are provided separately as the first generator 14 and the second generator 37. However, the rotational shafts of the gas turbine 2 and the steam turbine 5 may be combined into a single shaft, or the respective rotational shafts may be connected by a gear, so as to integrate the first generator 14 and the second generator 37 into a single generator.

It is also possible to optionally use the above embodiments in combination. Specifically, the boiler flue gas pipe 61 shown in FIG. 7 may be provided in the embodiment shown in FIG. 1, or the flue gas pipe for boiler 72 and the flue gas economizer 71 for a boiler, which are shown in FIG. 8, may be provided in the embodiment shown in FIG. 1.

Explanation of Reference:

[0045]

- 1: power generation plant (power generation system for ship)
- 2: gas turbine
- 3: flue gas economizer
- 4: boiler
- 5: steam turbine
- 6: control unit
- 14: first generator
- 16: furnace
- 17: steam drum
- 19: burner
- 29: circulation flow path
- 37: second generator
- 61: boiler flue gas pipe
- 71: flue gas economizer for boiler
- 72: flue gas pipe for boiler
- B1: first valve
- B2: second valve
- B3: third valve
- B4: fourth valve

CLAIMS

1. A power generation system for a ship, the system comprising:

a gas turbine that is driven by combustion gas;

a first generator that is driven by the gas turbine and generates power;

a flue gas economizer that generates steam by recovering heat from flue gas discharged from the gas turbine;

a boiler including a furnace and a steam drum;

a circulation flow path that is connected so as to use the steam drum as a steam separator for the flue gas economizer;

a circulating water pump provided in the circulation flow path;

a steam turbine that is driven by steam from the steam drum;

a second generator that is driven by the steam turbine and generates power; and

a control unit that has an operation mode of activating the circulating water pump and feeding water to the flue gas economizer when steam is not generated in the boiler.

2. The power generation system for a ship according to claim 1, comprising a control unit that controls a burner provided in the furnace, wherein

the control unit has, as an operation mode of the boiler, a boiler operation mode of igniting the burner in accordance with a load of the gas turbine.

3. The power generation system for a ship according to claim 1 or 2, comprising a control unit that controls a burner provided in the furnace, wherein

the control unit has, as an operation mode of the boiler, a boiler operation mode of igniting the burner during rated operation of the gas turbine.

4. The power generation system for a ship according to claim 1, comprising a control unit that has, as an operation mode, a first operation mode in which only the second generator performs power generation by stopping the gas turbine to ignite a burner provided in the furnace, and introducing steam from the steam drum into the steam turbine, and a second operation mode in which the first generator and the second generator perform power generation by driving the gas turbine, without igniting the burner, and by introducing steam generated by the flue gas economizer from the steam drum to the steam turbine, wherein

the control unit selects the operation mode in accordance with power needs for a ship.

5. The power generation system for a ship according to claim 4, wherein the control unit selects the first operation mode under a first load where a small amount of power is needed for the ship, and selects the second operation mode under a second load where a load is increased from the low load.

6. The power generation system for a ship according to claim 4, wherein the control unit has, as the operation mode, a third operation mode in which the first generator and the second generator perform power generation by igniting the burner provided in the furnace, and introducing steam from the steam drum into the steam turbine.

7. The power generation system for a ship according to claim 5, wherein the control unit has, as the operation mode, a third operation mode in which the first generator and the second generator perform power generation by igniting the burner provided in the furnace, and introducing steam from the steam drum into the steam turbine.

8. The power generation system for a ship according to claim 7, wherein the control unit selects the third operation mode under a second load where a load is increased from the second load.

9. The power generation system for a ship according to any one of claims 4 to 8, comprising a boiler flue gas pipe through which flue gas is directed from the boiler to the flue gas economizer.

10. The power generation system for a ship according to any one of claims 4 to 8, comprising:

- a flue gas economizer for a boiler that heats steam by recovering heat from flue gas discharged from the boiler; and

- a boiler flue gas pipe through which flue gas discharged from the boiler is directed to the flue gas economizer for a boiler.

11. The power generation system for a ship according to any one of claims 1 to 10, comprising:

- a boiler superheating pipe that connects the steam drum and the steam turbine to direct steam discharged from the drum to the steam turbine; and

- a boiler superheater that is provided on the boiler superheating pipe, wherein

- the boiler superheater is located within the furnace.

12. A power generation method for a power generation system for a ship, the method comprising:

- a gas turbine driving step of driving a gas turbine by

combustion gas;

a first power generating step of generating power by a first generator driven by the gas turbine;

a heat recovering step of recovering heat, in a flue gas economizer, from flue gas discharged from the gas turbine;

a steam separating step of separating steam from water, the steam being obtained in the heat recovering step by a steam drum in a boiler including a furnace and the steam drum;

a steam turbine driving step of driving a steam turbine by steam obtained in the steam separating step;

a second power generating step of generating power by a second generator driven by the steam turbine; and

a water feeding step of activating a circulating water pump and feeding water to the flue gas economizer when steam is not generated in the boiler.

13. A power generation plant comprising:

a gas turbine that is driven by combustion gas;

a first generator that is driven by the gas turbine and generates power;

a flue gas economizer that generates steam by recovering heat from flue gas discharged from the gas turbine;

a boiler including a furnace and a steam drum;

a circulation flow path that is connected so as to use the steam drum as a steam separator for the flue gas

economizer;

a steam turbine that is driven by steam from the steam drum;

a second generator that is driven by the steam turbine and generates power, and

a control unit that has, as an operation mode, a first operation mode in which only the second generator performs power generation by stopping the gas turbine to ignite a burner provided in the furnace, and introducing steam from the steam drum into the steam turbine, and a second operation mode in which the first generator and the second generator perform power generation by driving the gas turbine, without igniting the burner, and by introducing steam generated by the flue gas economizer from the steam drum to the steam turbine, wherein

the control unit selects the first operation mode under a first load where a small amount of power is needed, and selects the second operation mode under a second load where a load is increased from the low load.