

DESCRIPTION

Title of Invention: HYBRID PROPULSION SYSTEM OF SHIP AND CONTROL METHOD THEREOF

Technical Field

[0001] The present invention relates to a hybrid propulsion system of a ship including a main engine, a main generator, and an electric generator, and a control method thereof.

Background Art

[0002] As a conventional hybrid propulsion system of a ship, for example, a hybrid propulsion system disclosed in Non-Patent Literature 1 is known. The hybrid propulsion system is provided with a plurality of operation modes used to control a main engine, a main generator, and an electric generator. Under the circumstances, crew members of a ship including the hybrid propulsion system predict a thrust demand and an electric power demand of the ship, and set the operation mode which can cover the thrust demand and the electric power demand. According to the operation mode, the crew members manually perform switching between de-actuation (stop) and actuation (operation) of each of the main engine, the main generator, and the electric generator.

Citation List

Patent Literature

[0003] Non-patent Literature 1: Bueschen R, "WGA 23 - ein modernes Wellengeneratorsystem von Siemens", HANSA Vol. 120 No. 13 PP. 1203-1207, 1983

Summary of Invention

Technical Problem

[0004] In the hybrid propulsion system disposed in Non-Patent Literature 1 described above, the plurality of operation modes are set. However, there is a room for improvement in quick shifting to a proper operation mode.

[0005] The present invention has been made to solve the above-described problem, and an object of the present invention is to provide a hybrid propulsion system of a ship which is capable of quickly shifting a present operation mode to a proper operation mode.

Solution to Problem

[0006] According to an aspect of the present invention, a hybrid propulsion system of a ship, comprises a main engine (main engine for propulsion) which rotates a propeller via a driving power transmission mechanism to supply a thrust; a main generator which supplies electric power to an onboard bus; and an electric generator which performs an electric motor operation for rotating the propeller via the driving power transmission mechanism, by the electric power supplied from the main generator to the electric generator via the onboard bus, to supply the thrust, and a power generation operation for generating the electric power by rotational driving power supplied from the main engine to the electric generator via the driving power transmission mechanism and supplying the electric power to the onboard bus, the hybrid propulsion system being configured to operate via a console, the ship in one of a plurality of operation modes of combinations each including actuation or de-actuation of the main engine, actuation or de-actuation of the main generator, and the electric motor operation, the power generation operation or de-actuation of the electric generator, the hybrid propulsion system further comprising: a memory section which stores therein a permissible shifting operation mode combination which is a combination of an operation mode before shifting and an operation mode after shifting, in which the operation mode before shifting is permitted to be automatically shifted to the operation mode after shifting, and a control section configured to: calculate a fuel efficiency of each of the operation modes, and obtains an operation mode with the fuel efficiency higher than that of the present operation mode, when a present thrust demand and a present electric power demand fall within a suppliable thrust range in which the thrust can be supplied, and a suppliable electric power range in which the electric power can be supplied, respectively, the suppliable thrust range and the suppliable electric power range being set based on a change characteristic of suppliable electric power with respect to a change in a suppliable thrust, the change characteristic being defined for each of the operation modes, and automatically shift the present operation mode to the operation mode with the fuel efficiency higher than that of the present operation mode, which is selected from among operation modes after shifting, when a combination of the present operation mode and the obtained operation mode with the fuel efficiency

higher than that of the present operation mode matches the permissible shifting operation mode combination.

[0007] In accordance with this configuration, the combination of the operation modes, in which one of the operation modes is permitted to be automatically shifted to the other of the operation modes, can be stored in the memory section. In this configuration, in a case where the operation mode which has the supply capability higher than the demand and has the fuel efficiency higher than that of the present operation mode is stored as the operation mode to which the present operation mode is permitted to be automatically shifted, shifting from the present operation mode to this operation mode is performed. This makes it possible to quickly shift the present operation mode to the proper operation mode according to an operator's intention.

[0008] The hybrid propulsion system of the ship may be configured to display on the console, the operation mode with the fuel efficiency higher than that of the present operation mode. In this configuration, in a case where the combination of the present operation mode and the obtained operation mode with the fuel efficiency higher than that of the present operation mode does not match the permissible shifting operation mode combination, it becomes possible to quickly shift the present operation mode to the proper operation mode with the fuel efficiency higher than that of the present operation mode, via the console. Also, even in a case where the demand is significantly changed, frequent shifting of the operation mode can be suppressed based on the operator's determination. Further, the operator can know the operation mode with the higher fuel efficiency.

[0009] The hybrid propulsion system of the ship may be configured to cause the memory section to store therein the permissible shifting operation mode combination via the console or erase the permissible shifting operation mode combination stored in the memory section via the console. In this configuration, the operator can store the combination of the operation modes in which one of the operation modes is permitted to be automatically shifted to the other, by use of the console, or erase the combination of the operation modes in which one of the operation modes is permitted to be automatically shifted to the other, by use of the console. Therefore, the operation mode to which the present operation mode is automatically shifted can

be changed depending on the content of work.

[0010] In the hybrid propulsion system of the ship, the control section may be configured to: when two arbitrary operation modes are a combination of the operation modes in which the suppliable thrust range and the suppliable electric power range of one of the two operation modes are less than the suppliable thrust range and the suppliable electric power range, respectively, of the other of the two operation modes, automatically store in the memory section, the combination of the two arbitrary operation modes as the permissible shifting operation mode combination in which one of the two operation modes is the operation mode before shifting and the other of the two operation modes is the operation mode after shifting. In this configuration, the operation mode before shifting is automatically shifted to the operation mode after shifting which has the supply capability higher than that of the operation mode before shifting. This makes it possible to save the operator's trouble. Thus, the operator's operation becomes easier.

[0011] In the hybrid propulsion system of the ship, the control section may be configured not to: when two arbitrary operation modes are a combination of the operation modes in which a degree of redundancy set in one of the two operation modes is higher than a degree of redundancy set in the other of the two operation modes, automatically store in the memory section, the combination of the two arbitrary operation modes as the permissible shifting operation mode combination in which one of the two operation modes is the operation mode before shifting and the other of the two operation modes is the operation mode after shifting. In this configuration, the operation mode before shifting is not automatically shifted to the operation mode after shifting with the degree of redundancy lower than that of the present operation mode. Therefore, the operation mode can be shifted safely without degrading the degree of redundancy unintentionally.

[0012] In the hybrid propulsion system of the ship may be configured to display an alarm on the console when a degree of redundancy of the operation mode with the fuel efficiency higher than that of the present operation mode is lower than a degree of redundancy of the present operation mode. This allows the operator to recognize that the degree of redundancy will be reduced if the present operation mode is shifted to the operation mode with the higher fuel efficiency.

[0013] In the hybrid propulsion system, the control section may be configured to derive the degree of redundancy of the operation mode based on the number of each of the main engine, the main generator, and the electric generator which are actuated. In this configuration, since the degree of redundancy of the operation mode is automatically derived, the operator's trouble can be saved, and hence the operator's operation becomes easier.

[0014] In the hybrid propulsion system of the ship, the control section may be configured to derive the degree of redundancy of the operation mode based on a level according to a dynamic positioning class defined by International Maritime Organization, or a level according to a specified rule based on the dynamic positioning class. This makes it possible to derive the degree of redundancy according to the specified rule such as rules and regulations defined by, for example, a classification society.

[0015] In the hybrid propulsion system of the ship, the memory section may be configured to further store therein a combination of an operation mode before a failure, a failure state of a device in the operation mode before the failure, and an operation mode after the failure, as a failure shifting operation mode combination, and the control section may be configured to, in a case of occurrence of the failure, automatically shift the present operation mode to the operation mode after the failure of the failure shifting operation mode combination corresponding to the present operation mode as the operation mode before the failure and the failure state of the device. In this configuration, even when a failure occurs, the present operation mode can be shifted to the proper operation mode automatically and quickly.

[0016] In the hybrid propulsion system of the ship, the onboard bus may be dividable into a plurality of sections, the plurality of sections may be connected to each other via a breaker, and each of the operation modes may be set based on a combination of the actuation or the de-actuation of the main engine, the actuation or the de-actuation of the main generator, the electric motor operation, the power generation operation, or the de-actuation of the electric generator, and disconnection or connection of the breaker. In this configuration, the electric power can be supplied between the two sections via the breaker in a state in which the onboard bus is connected via the breaker. Therefore, a variation of the operation modes can be

increased.

[0017] In the hybrid propulsion system of the ship, the operation mode may include: an electric propulsion mode in which the main engine is de-actuated, the main generator is actuated, and the electric generator performs the electric motor operation; a propulsion increasing mode in which the main engine is actuated, the main generator is actuated, and the electric generator performs the electric motor operation; a parallel mode in which the main engine is actuated, the main generator is actuated, and the electric generator performs the power generation operation; a shaft generator mode in which the main engine is actuated, the main generator is de-actuated, and the electric generator performs the power generation operation; and a machine propulsion mode in which the main engine is actuated, the main generator is actuated, and the electric generator is de-actuated.

[0018] In the hybrid propulsion system of the ship, the memory section may be configured to store therein the permissible shifting operation mode combination in which the electric propulsion mode is the operation mode before shifting and the propulsion increasing mode is the operation mode after shifting, and the permissible shifting operation mode combination in which the shaft generator mode is the operation mode before shifting and the parallel mode is the operation mode after shifting, the control section may be configured to automatically shift the electric propulsion mode to the propulsion increasing mode, when the suppliable thrust of the electric propulsion mode is lower than a present thrust demand or the suppliable electric power of the electric propulsion mode is lower than a present electric power demand, while the ship is operated in the electric propulsion mode, and the control section may be configured to automatically shift the shaft generator mode to the parallel mode, when the suppliable thrust of the shaft generator mode is lower than the present thrust demand or the suppliable electric power of the shaft generator mode is lower than the present electric power demand, while the ship is operated in the shaft generator mode.

[0019] In the hybrid propulsion system of the ship, the memory section may be configured to store therein the permissible shifting operation mode combination of two of the electric propulsion mode, the propulsion increasing mode, the parallel mode, and the shaft generator mode, in which the propulsion increasing mode or the

parallel mode is the operation mode after shifting, and the control section may be configured to automatically shift the present operation mode to the propulsion increasing mode or the parallel mode, when the operation mode with the fuel efficiency higher than that of the present operation mode is the propulsion increasing mode or the parallel mode.

[0020] According to another aspect of the present invention, a control method of a hybrid propulsion system of a ship, comprises a main engine which rotates a propeller via a driving power transmission mechanism to supply a thrust; a main generator which supplies electric power to an onboard bus; and an electric generator which performs an electric motor operation for rotating the propeller via the driving power transmission mechanism, by the electric power supplied from the main generator to the electric generator via the onboard bus, to supply the thrust, and a power generation operation for generating the electric power by rotational driving power supplied from the main engine to the electric generator via the driving power transmission mechanism and supplying the electric power to the onboard bus, the hybrid propulsion system being configured to operate via a console, the ship in one of a plurality of operation modes of combinations each including actuation or de-actuation of the main engine, actuation or de-actuation of the main generator, and the electric motor operation, the power generation operation or de-actuation of the electric generator, the hybrid propulsion system further comprising: a memory section which stores therein a permissible shifting operation mode combination which is a combination of an operation mode before shifting and an operation mode after shifting, in which the operation mode before shifting is permitted to be automatically shifted to the operation mode after shifting, the control method comprising: calculating a fuel efficiency of each of the operation modes, and obtaining an operation mode with the fuel efficiency higher than that of the present operation mode, when a present thrust demand and a present electric power demand fall within a suppliable thrust range in which the thrust can be supplied, and a suppliable electric power range in which the electric power can be supplied, respectively, the suppliable thrust range and the suppliable electric power range being set based on a change characteristic of suppliable electric power with respect to a change in a suppliable thrust, the change characteristic being defined for each of

the operation modes, and automatically shifting the present operation mode to the operation mode with the fuel efficiency higher than that of the present operation mode, which is selected from among operation modes after shifting, when a combination of the present operation mode and the obtained operation mode with the fuel efficiency higher than that of the present operation mode matches the permissible shifting operation mode combination.

Advantageous Effects of Invention

[0021] The present invention has the above-described configuration, and can obtain an advantage that it is possible to provide a hybrid propulsion system of a ship which is capable of quickly shifting the present operation mode to a proper operation mode.

[0022] The above and further objects, features and advantages of the present invention will more fully be apparent from the following detailed description of preferred embodiment with reference to the accompanying drawings.

Brief Description of Drawings

[0023] Fig. 1 is a block diagram schematically showing a hybrid propulsion system of a ship according to Embodiment 1 of the present invention.

Fig. 2 is a block diagram showing operation modes of the hybrid propulsion system of Fig. 1.

Fig. 3 is a graph showing combinations of the operation mode before shifting and the operation mode after shifting, in which the operation mode before shifting is permitted to be automatically shifted to the operation mode after shifting, of the operation modes of Fig. 2.

Fig. 4 is a flowchart showing an exemplary control of the hybrid propulsion system of the ship of Fig. 1.

Fig. 5 is a block diagram schematically showing a hybrid propulsion system of a ship according to Embodiment 2 of the present invention.

Fig. 6 is a block diagram schematically showing a hybrid propulsion system of a ship according to Embodiment 3 of the present invention.

Fig. 7 is a flowchart showing an exemplary control of the hybrid propulsion system of Fig. 6.

Fig. 8 is a flowchart showing an exemplary control of a hybrid propulsion

system of a ship according to Embodiment 4 of the present invention.

Fig. 9 is a flowchart showing an exemplary control of a hybrid propulsion system of a ship according to Embodiment 5 of the present invention.

Fig. 10 is a graph showing a suppliable thrust (thrust which can be supplied) and a suppliable electric power (electric power which can be supplied) of each of the operation modes.

Fig. 11 is a flowchart showing an exemplary control of a hybrid propulsion system of a ship according to Embodiment 6 of the present invention.

Fig. 12 is a block diagram showing a hybrid propulsion system of a ship according to Embodiment 8 of the present invention.

Fig. 13 is a flowchart showing an exemplary control of a hybrid propulsion system of a ship according to Embodiment 9 of the present invention.

Description of Embodiments

[0024] (Finding as the Basis for the Present Invention)

The present inventors studied quick shifting to a proper operation mode, regarding a hybrid propulsion system of a ship. In the above-described conventional hybrid propulsion system, the crew members manually perform switching between actuation and de-actuation of the devices according to the operation mode. Therefore, the crew members have the trouble of performing switching of the operation mode, and cannot perform quick shifting of the operation mode. In addition, it is difficult to quickly select the proper operation mode.

[0025] Specifically, the ship called an offshore work ship which assists works of sea-based facilities such as an oil-drilling rig performs various works, for example, transportation of people and materials to the oil-drilling rig, towing of the oil-drilling rig (taking the oil-drilling rig in tow), hoisting of an anchor, and assisting of laying sea bed pipe lines. Depending on the content of the work, a thrust demand and an electric power demand of the hybrid propulsion system are varied. In the case of manual operation, the crew members cannot quickly select the operation mode. For this reason, in most cases, the operation mode having a supply capability which meets demands of all works is preset. Therefore, the fuel efficiency of the operation mode is not always optimized.

[0026] In order to carry out the works safely, the ship is required to hold its

position or orientation under the influences of wind, waves, tidal currents and the like. Furthermore, the ship is required to have a redundancy for maintaining its position holding capability, even when problems such as a failure or an abnormality occur. Therefore, the ship is required to control the hybrid propulsion system in view of the redundancy as well as the thrust demand and the electric power demand. [0027] However, the degree of redundancy which is required is varied depending on the content of the work of the ship, the position of the ship with respect to the oil-drilling rig, and external environment conditions such as weather and sea conditions. For this reason, the degrees of redundancy of the operation modes required for the works cannot be set uniformly. Therefore, in most cases, the crew members have a meeting prior to the work, decide the content of the work to be performed on that day, and set the degree of redundancy required for the hybrid propulsion system based on the content of the work, the external environment conditions, and the like. The crew members perform their works corresponding to the operation mode in the corresponding places, respectively, to supply the thrust and the electric power required for the content of the work while considering the degree of redundancy. However, for example, if an unplanned work occurs, the crew members cannot communicate with each other smoothly, and thereby the present operation mode may be shifted to the operation mode which does not meet the degree of redundancy, because the places where the crew members are located are distant from each other.

[0028] Under the circumstances, the present inventors discovered that combinations (permissible shifting operation mode combinations) of the operation mode before shifting and the operation mode after shifting, in which the operation mode before shifting is permitted to be automatically shifted to the operation mode after shifting, are prestored in a memory section, and thereby shifting from the present operation mode to a proper operation mode can take place quickly. Based on this finding, the present invention has been made.

[0029] Hereinafter, the embodiments of the present invention will be described with reference to the drawings. Throughout the drawings, the same or corresponding components are designated by the same reference symbols, and will not be described repeatedly.

[0030] (**Embodiment 1**)

Fig. 1 is a block diagram schematically showing a hybrid propulsion system 10 of a ship according to Embodiment 1. As shown in Fig. 1, the ship includes the hybrid propulsion system 10, a propeller 11, and a lever 12. The hybrid propulsion system 10 includes an electric power and thrust supply system 13, a control section 14, and a memory section 15. The electric power and thrust supply system 13 is connected to the propeller 11 and an onboard power load (load placed inside the ship) 21, and is configured to supply driving power and electric power which are generated in devices 17, 18, 19 to the loads 11, 12. The devices are configured to generate rotational driving power or electric power, and are a main engine 17, a main generator 18, and an electric generator 19. One or a plurality of main engine(s) 17, main generator(s) 18, and electric generator(s) 19 are provided inside the ship.

[0031] The main engine 17 is a major driving power source in the hybrid propulsion system 10. For example, a prime mover such as a diesel engine, a gas engine, or a gas turbine is used as the main engine 17. The main engine 17 is connected to a speed reduction device 20 and coupled to the propeller 11 and the electric generator 19 via the speed reduction device 20. The speed reduction device 20 is a driving power transmission mechanism. The speed reduction device 20 is configured to reduce a rotational speed of the driving power output from the main engine 17, increase torque, and transmit the driving power to the propeller 11 and the electric generator 19.

[0032] The main generator 18 is a major electric power source which supplies the electric power to the electric generator 19 and to the onboard power load 21 of the ship. For example, the main generator 18 is a device including a combination of the prime mover such as the diesel engine, the gas engine, or the gas turbine, and an electric generator, and is connected to an onboard bus (bus placed inside the ship) 22. The onboard power load 21 and the electric generator 19 are connected to the onboard bus 22. As the onboard power load 21, for example, there are a side thruster (not shown), an auxiliary machine (not shown), a console 23, an electric heater (not shown), and an electric light (lamp) (not shown). The onboard power load 21 and the electric generator 19 are connected to a PMS (power management system) 24. The onboard power load 21 and the electric generator 19 output to the

PMS 24 signals indicative of requests of the electric power required to operate the onboard power load 21 and the electric generator 19. The PMS 24 is connected to the control section 14 and the devices 18, 19 of the supply system 13 in addition to the onboard power load 21 and the electric generator 19. The PMS 24 derives the electric power demand of the hybrid propulsion system 10, based on the requested electric power from the power loads 19, 21, and output a signal indicative of the electric power demand to the control section 14. In addition, the PMS 24 controls the de-actuation and actuation of the devices 18, 19 of the supply system 13, in response to a shifting command of the operation mode received from the control section 14.

[0033] The electric generator 19 has an electric motor function and a power generation function (serves as an electric motor and a generator). The electric generator 19 supplies the driving power to the propeller 11 interactively with or independently of the main engine 17. Also, the electric generator 19 supplies the electric power to the onboard power load 21 interactively with or independently of the main generator 18. The electric generator 19 is connected to the speed reduction device 20 and coupled to the propeller 11 and the main engine 17 via the speed reduction device 20. Further, the electric generator 19 is connected to the main generator 18 and connected to the onboard power load 21 via the onboard bus 22. In a case where the electric generator 19 functions as the electric motor (performs an electric motor operation), it generates the rotational driving power by the electric power supplied from the main generator 18. The rotational driving power is transmitted from the electric generator 19 to the propeller 11 via the speed reduction device 20. By the rotational driving power, the propeller 11 is rotated and generates a thrust. In a case where the electric generator 19 functions as the generator for generating the electric power (performs a power generation operation), it generates the electric power by the rotational driving power supplied from the main engine 17, and supplies the electric power to the onboard power load 21 via the onboard bus 22.

[0034] A bidirectional power converter 25 is provided between the electric generator 19 and the main generator 18. The power converter 25 is an electric power conversion device which converts a frequency and voltage of AC power from

the main generator 18 and a frequency and voltage of the AC power from the electric generator 19. Specifically, the power converter 25 includes a first converter section 25a and a second power converter section 25b. In a case where the electric generator 19 performs the electric motor operation, the first power conversion section 25a converts the AC power from the main generator 18 into DC power, and the second power conversion section 25b converts the DC power into the AC power and outputs the AC power to the electric generator 19. In a case where the electric generator 19 performs the power generation operation, the second power conversion section 25b converts the AC power from the electric generator 19 into the DC power and the first power conversion section 25a converts the DC power into the AC power and outputs the AC power toward the onboard bus 22. By changing a switching frequency and a duty ratio when the power conversion sections 25a, 25b convert the DC power into the AC power in the above-described manner, the frequency and voltage of the AC power from the main generator 18 or the electric generator 19 are controlled.

[0035] The memory section 15 contains therein rated outputs of the devices 17, 18, 19, and a correspondence between the outputs of the devices 17, 18, 19 and fuel consumption amounts of the devices 17, 18, 19. The fuel consumption amounts of the devices 17, 18, 19 are defined as the amounts of fuel to be consumed by the devices 17, 18, 19 to generate the outputs.

[0036] The memory section 15 contains therein combinations (permissible shifting operation mode combinations) of the operation mode before shifting and the operation mode after shifting, in which the operation mode before shifting is permitted to be automatically shifted to the operation mode after shifting. There are a plurality of operation modes. The operation modes are set using combinations of the actuation or de-actuation of the main engine 17, the actuation or de-actuation of the main generator 18, and the electric motor operation, power generation operation or de-actuation of the electric generator 19. The permissible shifting operation mode combination is set based on, for example, the degree of redundancy and supply capability (suppliable thrust (thrust which can be supplied)), suppliable electric power (electric power which can be supplied) of the hybrid propulsion system 10. The permissible shifting operation mode combination is prestored in

the memory section 15, manually by an operator such as the crew member, and/or automatically by the control section 14. One or a plurality of permissible shifting operation mode combination(s) may be stored in the memory section 15.

[0037] The control section 14 calculates the fuel efficiency of each of the operation modes, when a present thrust demand and a present electric power demand fall within a suppliable thrust range in which the thrust can be supplied, and a suppliable electric power range in which the electric power can be supplied, respectively, which are set based on a change characteristic of the suppliable electric power, with respect to a change in the suppliable thrust, the change characteristic being defined for each of the operation modes. Then, the control section 14 obtains the operation mode which has the fuel efficiency higher than that of a present operation mode. In a case where the combination of this operation mode with the higher fuel efficiency and the present operation mode matches the permissible shifting operation mode combination, the control section 14 shifts the present operation mode to the operation mode with the higher fuel efficiency, of the operation modes after shifting.

[0038] The fuel efficiency of the hybrid propulsion system 10 is defined as the fuel consumption amount of the hybrid propulsion system 10 with respect to the supplied thrust and supplied electric power of the hybrid propulsion system 10 in a case where the ship is operated in each of the operation modes. The fuel efficiency is calculated using a well-known calculation method. The supplied thrust of the hybrid propulsion system 10 is a sum of supplied thrusts of the devices 17, 18, 19 which are actuated (operating), and the supplied electric power of the hybrid propulsion system 10 is a sum of supplied electric powers of the devices 17, 18, 19 which are actuated (operating). The fuel consumption amount of the hybrid propulsion system 10 is a total of the amounts of fuel to be consumed by the devices 17, 18, 19 to output the supplied thrust which meets the thrust demand, and to output the supplied electric power which meets the electric power demand. The fuel consumption amount of the devices 17, 18, 19 is derived based on a relationship between the fuel consumption amount and the output of each of the devices 17, 18, 19, which is stored in the memory section 15, and the number of the devices 17, 18, 19 which are actuated (operating). The number of the devices 17, 18, 19 which are actuated (operating) means, for example, the number of all of the devices 17, 18, 19

in the supply system 13, a specified number of the devices 17, 18, 19 in the supply system 13, or a minimum number of the devices 17, 18, 19 in the supply system 13, which meet the demand. The number of the devices 17, 18, 19 which are actuated (operating) is decided depending on whether all of the devices 17, 18, 19 are always actuated, the devices 17, 18, 19 of the specified number are always actuated, or the devices 17, 18, 19 of a required number are actuated while performing start-up or stop according to the demand, in the corresponding operation mode.

[0039] The propeller 11 is a propulsor which provides a thrust to the ship. One or a plurality of propellers are provided on the ship. The propeller 11 is connected to the speed reduction device 20. The propeller 11 receives the rotational driving power output from the main engine 17 and/or the electric generator 19 which performs the electric motor operation, via the speed reduction device 20, and converts the rotational driving power into the thrust. The thrust of the propeller 11 is controlled by the rotational speed of the propeller 11 which is adjusted by the speed reduction device 20, and a pitch angle (blade angle) of the propeller 11 which is adjusted by a pitch angle adjustment mechanism (not shown).

[0040] The lever 12 is a control bar (rod) operated by the operator to input the thrust demand of the ship. For example, a throttle lever 12 is used as the lever 12, and is provided on the console 23. The lever 12 is connected to a PCS (propulsion control system) 26. An operation amount of the lever 12 operated by the operator is output to the PCS 26. The PCS 26 is connected to the control section 14, a controller (not shown) of the main engine 17, and a pitch angle adjustment mechanism, in addition to the lever 12. The PCS 26 derives the thrust demand, the rotational speed of the main engine 17, and the pitch angle of the propeller 11, based on the operation amount of the lever 12. Then, the PCS 26 outputs the thrust demand to the control section 14, outputs the rotational speed of the main engine 17 to the controller of the main engine 17, and outputs the pitch angle of the propeller 11 to the pitch angle adjustment mechanism. The thrust of the propeller 11 is controlled based on the rotational speed and pitch angle of the propeller 11.

[0041] The control section 14, the PMS 24 and the PCS 26 may be configured as a single controller or three separate controllers, respectively. In a case where the control section 14, the PMS 24 and the PCS 26 are configured as the single

controller, the functions of the control section 14, the PMS 24 and the PCS 26 are performed by programs stored in the controller.

[0042] Next, the operation modes of the hybrid propulsion system 10 of the ship will be described. Figs. 2A to 2E are block diagrams showing the operation modes, respectively, of the hybrid propulsion system 10 of the ship. For example, there are five kinds of operation modes shown in Figs. 2A to 2E. Among these operation modes, a machine propulsion mode of Fig. 2A is the operation mode in which the electric generator 19 is de-actuated, and the main engine 17 and the main generator 18 are actuated and operative independently. An electric propulsion mode, a propulsion increasing mode, a parallel mode, and a shaft generator mode shown in Figs. 2B to 2E, respectively, are the operation modes in which the electric generator 19 is actuated and operative interactively with the main engine 17 or the main generator 18.

[0043] In the machine propulsion mode of Fig. 2A, the main engine 17 is actuated, the main generator 18 is actuated, and the electric generator 19 is de-actuated. In this machine propulsion mode, the main engine 17 supplies the rotational driving power to the propeller 11 via the speed reduction device 20. The main generator 18 supplies the electric power to the onboard power load 21 (Fig. 1) via the onboard bus 22. In this way, the thrust of the propeller 11 is provided by the rotational driving power supplied from the main engine 17, and the electric power of the onboard power load 21 is supplied from the main generator 18.

[0044] In the electric propulsion mode of Fig. 2B, the main engine 17 is de-actuated, the main generator 18 is actuated, and the electric generator 19 performs the electric motor operation. In this electric propulsion mode, the main generator 18 supplies the electric power to the onboard power load 21 via the onboard bus 22, and supplies the electric power to the electric generator 19 via the power converter 25. The electric generator 19 generates the rotational driving power by the electric power supplied from the main generator 18, and supplies the rotational driving power to the propeller 11 via the speed reduction device 20. In this way, the thrust of the propeller 11 is provided by the rotational driving power supplied from the electric generator 19. In general, the output of the electric generator 19 is designed to be smaller than that of the main engine 17. For this

reason, a suppliable thrust (a thrust which can be supplied) of the electric propulsion mode is smaller than that of the machine propulsion mode of Fig. 2A.

[0045] In the propulsion increasing mode of Fig. 2C, the main engine 17 is actuated, the main generator 18 is actuated, and the electric generator 19 performs the electric motor operation. In this propulsion increasing mode, the main generator 18 supplies the electric power to the onboard power load 21 via the onboard bus 22, and supplies the electric power to the electric generator 19. The electric generator 19 and the main engine 17 supply the rotational driving power to the propeller 11 via the speed reduction device 20. In this way, the thrust of the propeller 11 is provided by the rotational driving power supplied from the electric generator 19 in addition to the rotational driving power supplied from the main engine 17. For this reason, the suppliable thrust of the propulsion increasing mode is larger than that of the machine propulsion mode of Fig. 2A.

[0046] In the parallel mode of Fig. 2D, the main engine 17 is actuated, the main generator 18 is actuated, and the electric generator 19 performs the power generation operation. In this parallel mode, the main generator 18 supplies the electric power to the onboard power load 21 via the onboard bus 22. The main engine 17 supplies the rotational driving power to the propeller 11 and to the electric generator 19. The electric generator 19 generates the electric power by the rotational driving power supplied from the main engine 17, and supplies the electric power to the onboard power load 21 via the onboard bus 22. In this way, the electric generator 19 as well as the main generator 18 supplies the electric power to the onboard power load 21. For this reason, the suppliable electric power of the parallel mode is larger than that of the machine propulsion mode of Fig. 2A.

[0047] In the shaft generator mode of Fig. 2E, the main engine 17 is actuated, the main generator 18 is de-actuated, and the electric generator 19 performs the power generation operation. In this shaft generator mode, the main engine 17 supplies the rotational driving power to the propeller 11 and to the electric generator 19. The electric generator 19 generates the electric power by the rotational driving power supplied from the main engine 17, and supplies the electric power to the onboard power load 21 via the onboard bus 22. In this way, only the electric generator 19 supplies the electric power to the onboard power load 21. In a case

where the output of the electric generator 19 is designed to be smaller than that of the main generator 18, the suppliable electric power of the shaft generator mode is smaller than that of the machine propulsion mode of Fig. 2A.

[0048] In a case where the hybrid propulsion system 10 includes a plurality of main engines 17, a plurality of main generators 18, and a plurality of electric generators 19, the operation modes may or may not be differentiated from each other depending on the number of and outputs of the devices 17, 18, 19 which are actuated (operating). For example, the hybrid propulsion system 10 of Fig. 1 includes two main generators 18. In this case, the electric propulsion mode in which one main generator 18 and one electric generator 19 are actuated, and the electric propulsion mode in which two main generators 18 and one electric generator 19 are actuated, may be recognized as different operation modes or the same operation mode.

[0049] Further, the operation modes may be differentiated from each other, depending on the degree of redundancy. For example, the operation modes in which the number of the devices 17, 18, 19 which are actuated (operating) is different and the degree of redundancy is equal, may be recognized as the same operation mode. In this case, the supply capability is derived based on the number of all of the devices 17, 18, 19 which are actuated (operating), and the rated outputs of the devices 17, 18, 19, in the operation mode. The fuel efficiency is derived based on the minimum number of the devices 17, 18, 19 which are actuated (operating) and whose supply capabilities meet the demand, and the rated outputs of the devices 17, 18, 19. In contrast, the operation modes in which the number of the devices 17, 18, 19 which are actuated (operating) is different and the degree of redundancy is different may be recognized as different operation modes. In this case, the supply capability and the fuel efficiency are derived based on all of the devices 17, 18, 19 which are actuated (operating), and the rated outputs of the devices 17, 18, 19, in the operation mode.

[0050] Next, the permissible shifting operation mode combinations will be described. Fig. 3 is a graph showing the permissible shifting operation mode combinations. The graph of Fig. 3 is divided into 10 blocks by a center longitudinal line, a center lateral line, an upper diagonal line and a lower diagonal line. In the graph of Fig. 3, the blocks which are located rightward relative to the

center longitudinal line indicate the operation modes in which the main engine 17 is actuated (operating), while the blocks which are located leftward relative to the center longitudinal line indicate the operation modes in which the main engine 17 is de-actuated. The blocks located above the center lateral line indicate the operation modes in which the main generator 18 is actuated, while the blocks located below the center lateral line indicate the operation mode in which the main generator 18 is de-actuated. The blocks located leftward relative to and above the upper diagonal line are the operation modes in which the electric generator 19 performs the electric motor operation. The blocks located between the upper diagonal line and the lower diagonal line indicate the operation modes in which the electric generator 19 is de-actuated. The blocks located rightward relative to and below the lower diagonal line are the operation modes in which the electric generator 19 performs the power generation operation.

[0051] Fig. 3 shows the operation mode (mooring mode) in which the ship is moored, in addition to the above-described five operation modes of Figs. 2A to 2E. In this mooring mode, the main engine 17 is de-actuated, the main generator 18 is actuated, and the electric generator 19 is de-actuated. In this state, the rotational driving power is not supplied to the propeller 11, while the electric power is supplied from the electric generator 19 to the onboard power load 21 via the onboard bus 22.

[0052] In Fig. 3, arrows between the operation modes indicate shifting of the operation mode. Each solid-line arrow indicates that the operation mode before shifting at a base end of the arrow is permitted to be automatically shifted to the operation mode after shifting at a tip end of the arrow. Combinations of the operation modes in which one of the operation mode is permitted to be automatically shifted to the other (permissible shifting operation mode combinations) are stored in the memory section 15. In contrast, each dotted-line arrow indicates that the operation mode before shifting at a base end of the arrow is not permitted to be automatically shifted to the operation mode after shifting at a tip end of the arrow. In this case, the operator can manually shift the operation mode before shifting to the operation mode after shifting.

[0053] In this example, as indicated by the solid-line arrows of Fig. 3, four combinations of the operation modes are stored in the memory section 15 as the

permissible shifting operation mode combinations. The four permissible shifting operation mode combinations are the shifting of the operation modes, including the shifting from the electric propulsion mode to the propulsion increasing mode, the shifting from the shaft generator mode to the parallel mode, the shifting from the propulsion increasing mode to the parallel mode, and the shifting from the parallel mode to the propulsion increasing mode.

[0054] In Fig. 3, shifting among the five operation modes except the mooring mode, which is indicated by arrows, is set in such a manner that switching between de-actuation and actuation of one kind of device 17, 18, 19 is performed. For example, the shifting from the electric propulsion mode to the propulsion increasing mode is performed by switching the main engine 17 from de-actuation to actuation. The shifting from the propulsion increasing mode to the parallel mode is performed by switching the electric generator 19 from the electric motor operation to the power generation operation. It should be noted that shifting of the operation mode may be set in such a manner that switching between the de-actuation and actuation of two or more kinds of devices 17, 18, 19 is performed.

[0055] Next, the control method of the hybrid propulsion system 10 of the ship will be described. Fig. 4 is a flowchart showing an exemplary control of the hybrid propulsion system 10 of the ship. For example, the operator decides the content of work of the ship, and operates the lever 12 and the onboard power load 21 according to the content of work. Thereby, the operation amount of the lever 12 is input to the PCS 26, and requested electric power of the onboard power load 21 is input to the PMS 24. The PMS 24 sums up the requested electric power from the onboard power load 21 to derive the electric power demand of the hybrid propulsion system 10, and outputs the electric power demand to the control section 14. The PCS 26 derives the thrust demand based on the operation amount of the lever 12, and outputs the thrust demand to the control section 14. As shown in Fig. 4, the control section 14 obtains the thrust demand from the PCS 26, and obtains the electric power demand from the PMS 24 (step S1).

[0056] The control section 14 derives the supply capability of the operation mode based on the rated outputs of the devices 17, 18, 19 and the number of devices 17, 18, 19 which are actuated (operating). The control section 14 finds the operation mode

having the supply capability which meets the demand, whose suppliable thrust is larger than the thrust demand and suppliable electric power is larger than the electric power demand. Then, the control section 14 calculates the fuel efficiency of the operation mode having the supply capability, which meets the demand, with reference to a correspondence between the outputs of the devices 17, 18, 19 and the fuel consumption amounts of the devices 17, 18, 19, which is stored in the memory section 15 (step S2).

[0057] Among the operation modes having the supply capabilities which meet the demand, the control section 14 finds the operation mode with the fuel efficiency higher than that of the present operation mode. Then, the control section 14 determines whether or not the operation mode with the higher fuel efficiency matches the operation mode after shifting and the present operation mode matches the operation mode before shifting, regarding the permissible shifting operation mode combination(s) stored in the memory section 15 (step S3). When the control section 14 determines that the combination of the present operation mode and the operation mode with the higher fuel efficiency does not match the permissible shifting operation mode combination (step S3: NO), the control section 14 returns to step S1 and repeats steps S1 to S3. In this case, the operation of the hybrid propulsion system 10 of the ship in the present operation mode with the higher fuel efficiency is maintained.

[0058] On the other hand, when the control section 14 determines that the shifting from the present operation mode to the operation mode with the higher fuel efficiency matches the permissible shifting operation mode combination (step S3: YES), the control section 14 executes shifting of the operation mode (step S4). In a case where the fuel efficiencies of the plurality of operation modes are higher than that of the present operation mode, the control section 14 shifts the present operation mode to the operation mode with the highest fuel efficiency, among the plurality of operation modes with the higher fuel efficiencies.

[0059] The control section 14 outputs a shifting command for shifting from the present operation mode to the operation mode with the higher efficiency, to the PCS 26 and the PMS 24. In response to the shifting command, the PCS 26 outputs to the controller of the main engine 17, the rotational speed of the main engine 17

corresponding to the operation amount of the lever 12, and outputs the pitch angle of the propeller 11 to the pitch angle adjustment mechanism. Thereby, the supplied thrust of the propeller 11 is controlled according to the operation mode after shifting. The PMS 24 performs switching between the actuation and de-actuation of each of the main engine 17 and the main generator 18, and switching among the electric motor operation, the power generation operation, and de-actuation of the electric generator 19, according to the operation mode after shifting. Thereby, the supplied electric power is controlled according to the operation mode after shifting.

[0060] In accordance with the above-described configuration, when the combination of the present operation mode and the operation mode with the higher fuel efficiency matches the permissible shifting operation mode combination, the control section 14 executes shifting of the operation mode. This allows the operation mode to be automatically shifted, which can save the operator's trouble, and quickly switch the operation mode.

[0061] Among the operation modes having the supply capabilities higher than the demand, the operation mode with the fuel efficiency higher than that of the present operation mode is selected as the operation mode after shifting. Therefore, it becomes possible to quickly shift the present operation mode to the proper operation mode with the improved fuel efficiency, while meeting the demand.

[0062] Further, since the permissible shifting operation mode combination(s) is/are pre-stored in the memory section 15, the present operation mode can be shifted to the proper operation mode. For example, the operator decides the content of work on that day in a meeting, and sets the degree of redundancy based on the content of work, the external environment conditions, etc.. At this time, the operator can store in the memory section 15 the permissible shifting operation mode combination in view of the degree of redundancy. This makes it possible to avoid shifting to the operation mode which has the degree of redundancy lower than that of the present operation mode, against the operator's intention. As a result, it becomes possible to quickly shift the present operation mode to the proper operation mode while securing safety.

[0063] It should be noted that the operation mode with the fuel efficiency higher than that of the present operation mode may be the operation mode with the highest

fuel efficiency. In this case, in step S3 of Fig. 4, the control section 14 finds the operation mode with the highest fuel efficiency, among the operation modes whose suppliable thrusts are larger than the thrust demand and whose suppliable electric powers are higher than the electric power demand. Then, when the present operation mode and the operation mode with the highest fuel efficiency match the operation mode before shifting and the operation mode after shifting, respectively, of the permissible shifting operation mode combination (step S3: YES), the control section 14 executes shifting of the operation mode (step S4).

[0064] In this way, when the combination of the operation modes, in which the present operation mode is shifted to the operation mode with the highest fuel efficiency, matches the permissible shifting operation mode combination, the control section 14 automatically executes shifting of the operation mode. As a result, it becomes possible to quickly shift the present operation mode to the proper operation mode prestored in the memory section 15 according to the operator's intention.

[0065] Regarding the ship which assists works of sea-based facility such as an oil-drilling rig, the electric power demand and the thrust demand significantly fluctuate. Even in such a case, unless the operation mode after shifting has the highest fuel efficiency and the combination of the operation modes in which the present operation mode is shifted to the operation mode with the highest fuel efficiency is stored in the memory section 15, the control section 14 does not automatically execute shifting of the operation mode. Thus, since the shifting of the operation mode is not performed frequently, the frequency at which the actuation and de-actuation of the devices 17, 18, 19 occur is reduced.

[0066] **(Embodiment 2)**

The hybrid propulsion system 10 of the ship according to Embodiment 2 is configured in such a manner that the onboard bus 22 is dividable into a plurality of sections, and the plurality of sections are connected to each other via a breaker 27. In this case, the operation mode is decided based on a combination of the actuation or de-actuation of the main engine 17, the actuation or de-actuation of the main generator 18, the electric motor operation, the power generation operation, or de-actuation of the electric generator 19, and disconnection (cut-off) or connection of the breaker 27.

[0067] This will be described specifically. Fig. 5 is a block diagram schematically showing the hybrid propulsion system 10 of the ship according to Embodiment 2. As shown in Fig. 5, for example, the onboard bus 22 is divided into two sections, and the two supply systems 13 are provided in these sections, respectively. The breaker 27 is provided between the two sections of the onboard bus 22. The breaker 27 is a device which disconnects (cuts-off) and connects the onboard bus 22. For example, a bus tie breaker (BTB) is used as the breaker 27. One or a plurality of breaker(s) 27 is/are provided on the onboard bus 22 and connected to the control section 14.

[0068] Normally, the onboard bus 22 is disconnected (cut-off) by the breaker 27, the electric power is not supplied between the two supply systems 13, and the two supply systems 13 are operated independently. In this state, in a case where each of the electric generators 19 performs the electric motor operation, the thrust is generated by the electric power supplied from the main generator 18, within the same supply system 13, as in the electric propulsion mode or the propulsion increasing mode.

[0069] In contrast, in a state in which the onboard bus 22 is connected by the breaker 27, the electric power can be supplied between the two supply systems 13. In this state, the electric power can be supplied from one of the two supply systems 13 to the other of the two supply systems 13 via the onboard bus 22. In this case, one of the supply systems 13 can be operated in an external power supply mode in which the electric generator 19 generates the thrust by the electric power supplied from the other of the two supply systems 13.

[0070] For example, in the example of Fig. 5, the supply system 13 operated in the shaft generator mode and the supply system 13 operated in the external power supply mode are connected to each other via the breaker 27. In Fig. 5, the supply system 13 located at the left side of the breaker 27 is operated in the shaft generator mode. In the shaft generator mode, the electric generator 19 performs the power generation operation and supplies the electric power to the onboard power load 21 via the onboard bus 22. In contrast, the supply system 13 located at the right side of the breaker 27 in Fig. 5 is operated in the external power supply mode. In the external power supply mode, the main engine 17 and the main generator 18 are de-actuated,

and the electric generator 19 performs the electric motor operation. In this case, the electric generator 19 generates the rotational driving power by the electric power supplied from the supply system 13 operated in the shaft generator mode, and rotates the propeller 11 to obtain the thrust.

[0071] The fuel efficiency of the hybrid propulsion system 10 is derived based on the fuel consumption amount of the hybrid propulsion system 10 with respect to the supplied thrust and supplied electric power of the hybrid propulsion system 10. In either one of the hybrid propulsion system 10 in which the onboard bus 22 is disconnected (cut-off) by the breaker 27, and the hybrid propulsion system 10 in which the onboard bus 22 is connected by the breaker 27, the fuel consumption amount of the hybrid propulsion system 10 is a sum of the fuel consumption amounts of the devices 17, 18, 19. Also, the supplied thrust of the hybrid propulsion system 10 is a sum of the supplied thrusts of the devices 17, 18, 19, while the supplied electric power of the hybrid propulsion system 10 is a sum of the supplied electric powers of the devices 17, 18, 19.

[0072] In accordance with the above-described configuration, by connecting the onboard bus 22 via the breaker 27, the supply system 13 can be operated in the external power supply mode. This can increase a variation of the operation modes. Therefore, the present operation mode can be shifted to the proper operation mode with improved safety. Further, options of the operation mode with the higher fuel efficiency are increased, and thus the present operation mode can be shifted to the proper operation mode with the higher fuel efficiency.

[0073] The steps of Embodiment 1 may be performed in Embodiment 2, and thereby the same advantages as those of Embodiment 1 can be obtained.

[0074] **(Embodiment 3)**

The hybrid propulsion system 10 of the ship according to Embodiment 3 is configured to display the operation mode with the higher fuel efficiency on the console 23. Fig. 6 is a block diagram showing the hybrid propulsion system 10 of the ship according to Embodiment 3. As shown in Fig. 6, a display section 28 is connected to the control section 14, and provided on, for example, the console 23.

[0075] Fig. 7 is a flowchart showing an exemplary control of the hybrid propulsion system 10 of the ship according to Embodiment 3. In the flow of Fig. 7, steps S1 to

S4 of Fig. 4 are also performed. It should be noted that in the flow of Fig. 7, a process (step S5) for displaying the operation mode with the higher fuel efficiency is performed after step S4.

[0076] Specifically, when the control section 14 determines that the combination of the present operation mode and the operation mode with the higher fuel efficiency matches the permissible shifting operation mode combination (step S3: YES), the control section 14 shifts the present operation mode to the operation mode with the higher fuel efficiency (step S4). Also, the control section 14 causes the display section 28 to display the operation mode with the higher fuel efficiency (step S5).

[0077] In accordance with the above-described configuration, when the combination of the present operation mode and the operation mode with the higher fuel efficiency matches the permissible shifting operation mode combination, the control section 14 executes shifting of the operation mode, and causes the display section 28 to display the operation mode with the higher fuel efficiency. This allows the operator to know the operation mode to be executed after the shifting.

[0078] Further, the steps of Embodiment 1 may be performed in Embodiment 3, and thereby the same advantages as those of Embodiment 1 can be obtained. Moreover, the hybrid propulsion system 10 according to Embodiment 3 may further include the breaker 27 of Fig. 5, and thereby the same advantages as those of Embodiment 2 can be obtained.

[0079] **(Embodiment 4)**

The hybrid propulsion system 10 of the ship according to Embodiment 4 is configured to display the operation mode with the higher fuel efficiency on the console 23. As shown in Fig. 6, the display section 28 of the console 23 is connected to the control section 14. Fig. 8 is a flowchart showing an exemplary control of the hybrid propulsion system 10 of the ship according to Embodiment 4. In the flow of Fig. 8, steps S1 to S4 of Fig. 4 are also performed. It should be noted that in the flow of Fig. 8, a process (step S6) for displaying the operation mode with the higher fuel efficiency is performed after step S3.

[0080] Specifically, when the control section 14 determines that the combination of the present operation mode and the operation mode with the higher fuel efficiency does not match the permissible shifting operation mode combination (step S3: NO),

the control section 14 causes the display section 28 to display the operation mode with the higher fuel efficiency (step S6). In this case, shifting from the present operation mode to the operation mode with the higher fuel efficiency is not performed automatically. However, the operator can know the operation mode with the higher fuel efficiency. This allows the operator to manually shift the present operation mode to the operation mode with the higher fuel efficiency, although the operation mode with the higher fuel efficiency is not the operation mode to which the present operation mode is permitted to be automatically shifted. As a result, the present operation mode can be shifted to the proper operation mode according to the operator's intention.

[0081] Alternatively, in the flow of Fig. 8, as in the flow of Fig. 7, a process (step S5) for displaying the operation mode with the higher fuel efficiency may be performed after step S4. Thus, the same advantages as those of Embodiment 3 can be obtained.

[0082] Further, the steps of Embodiment 1 may be performed in Embodiment 4, and thereby the same advantages as those of Embodiment 1 can be obtained. Moreover, the hybrid propulsion system 10 according to Embodiment 4 may further include the breaker 27 of Fig. 5, and thereby the same advantages as those of Embodiment 2 can be obtained.

[0083] **(Embodiment 5)**

The hybrid propulsion system 10 of the ship according to Embodiment 5 is configured to display the operation mode with the higher fuel efficiency on the console 23. As shown in Fig. 6, the display section 28 of the console 23 is connected to the control section 14. Fig. 9 is a flowchart showing an exemplary control of the hybrid propulsion system 10 of the ship according to Embodiment 5. In the flow of Fig. 9, steps S1 to S4 of Fig. 4 are also performed. In the flow of Fig. 9, the control section 14 determines whether or not the degree of redundancy of the operation mode with the higher fuel efficiency is lower than that of the present operation mode (step S7) after step S3.

[0084] Specifically, when the control section 14 determines that the combination of the present operation mode and the operation mode with the higher fuel efficiency does not match the permissible shifting operation mode combination (step S3: NO),

the control section 14 derives the degree of redundancy of the present operation mode and the degree of redundancy of the operation mode with the higher fuel efficiency. When the control section 14 determines that the degree of redundancy of the operation mode with the higher fuel efficiency is higher than that of the present operation mode (step S7: NO), the degree of redundancy of the operation mode will not be reduced even when the present operation mode is shifted to the operation mode with the higher fuel efficiency. Therefore, the control section 14 causes the display section 28 to display the operation mode with the higher fuel efficiency (step S6). Since the operator can know the operation mode with the higher fuel efficiency, the operator can manually shift the present operation mode to the operation mode with the higher fuel efficiency. As a result, the present operation mode can be shifted to the proper operation mode according to the operator's intention.

[0085] On the other hand, when the control section 14 determines that the degree of redundancy of the operation mode with the higher fuel efficiency is lower than that of the present operation mode (step S7: YES), the degree of redundancy of the operation mode will be reduced if the present operation mode is shifted to the operation mode with the higher fuel efficiency. Therefore, the control section 14 causes the display section 28 to display the operation mode with the higher fuel efficiency and an alarm stating that the degree of redundancy will be reduced if the present operation mode is shifted to the operation mode with the higher fuel efficiency (step S8). In this case, the operation mode with the higher fuel efficiency may not be displayed. By displaying the alarm stating that the degree of redundancy will be reduced if the present operation mode is shifted to the operation mode with the higher fuel efficiency, the operator can pay attention to this. Therefore, the operator can manually shift the present operation mode to the operation mode with the higher fuel efficiency in view of reduction of the degree of redundancy.

[0086] Alternatively, in the flow of Fig. 9, as in the flow of Fig. 7, a process (step S5) for displaying the operation mode with the higher fuel efficiency may be performed after step S4. Thus, the same advantages as those of Embodiment 3 can be obtained.

[0087] Further, the steps of Embodiment 1 may be performed in Embodiment 5, and thereby the same advantages as those of Embodiment 1 can be obtained. Moreover, the hybrid propulsion system 10 according to Embodiment 5 may further include the breaker 27 of Fig. 5, and thereby the same advantages as those of Embodiment 2 can be obtained.

[0088] **(Embodiment 6)**

In the hybrid propulsion system 10 of the ship according to Embodiment 6, two arbitrary operation modes are a combination of the operation modes in which the suppliable thrust range and the suppliable electric power range of one of the two operation modes are less than the suppliable thrust range and the suppliable electric power range, respectively, of the other of the two operation modes. In this case, in this combination of operation modes, one of the two operation modes is the operation mode before shifting and the other of the two operation modes is the operation mode after shifting. The control section 14 causes the memory section 15 to store therein this combination as the permissible shifting operation mode combination.

[0089] Now, the suppliable thrust (thrust which can be supplied) and suppliable electric power (electric power which can be supplied) of each of the operation modes will be described. Fig. 10 is a graph showing the suppliable thrust and the suppliable electric power of each of the operation modes. In the graph, a vertical axis indicates the suppliable electric power, and a horizontal axis indicates the suppliable thrust. In Fig. 10, OA indicates the rated thrust of the main engine 17, and OD indicates the rated electric power of the main generator 18. OF indicates the rated thrust of the electric generator 19 which performs the electric motor operation, and OC indicates the rated electric power of the electric generator 19 which performs the power generation operation.

[0090] Fig. 10 shows the suppliable thrust range and suppliable electric power range which are set based on a change characteristic of the suppliable electric power with respect to a change in the suppliable thrust, the change characteristic being defined for each of the operation modes. It should be noted that the supply capability includes the suppliable thrust (thrust which can be supplied) and the suppliable electric power (electric power which can be supplied) which are defined

by the suppliable thrust range and the suppliable electric power range, respectively.

[0091] A range defined by OABC indicates the suppliable thrust range and suppliable electric power range of the shaft generator mode. In the shaft generator mode, the main engine 17 supplies the thrust of the propeller 11 (the rotational driving power of the propeller 11) and supplies the driving power to the electric generator 19 which performs the power generation operation, and the electric generator 19 converts the driving power supplied from the main engine 17 into the electric power and supplies the electric power. Therefore, the maximum suppliable thrust of the shaft generator mode is the rated thrust (OA) of the main engine 17, and the maximum suppliable electric power of the shaft generator mode is the rated electric power (OC) of the electric generator 19.

[0092] A range defined by ODEF indicates the suppliable thrust range and suppliable electric power range of the electric propulsion mode. In the electric propulsion mode, the main generator 18 supplies the electric power and the electric power to the electric generator 19 which performs the electric motor operation, and the electric generator 19 converts the electric power supplied from the main generator 18 into the thrust of the propeller 11 and supplies the thrust. Therefore, the maximum suppliable thrust of the electric propulsion mode is the rated thrust (OF) of the electric generator 19, and the maximum suppliable electric power of the electric propulsion mode is the rated electric power (OD) of the main generator 18.

[0093] A range defined by OAGHI indicates the suppliable thrust range and suppliable electric power range of the parallel mode. In the parallel mode, the main engine 17 supplies the thrust of the propeller 11 and the driving power to the electric generator 19 which performs the power generation operation, the electric generator 19 converts the driving power supplied from the main engine 17 into the electric power and supplies the electric power, and the main generator 18 supplies the electric power. Therefore, the maximum suppliable thrust of the parallel mode is the rated thrust (OA) of the main engine 17, and the maximum suppliable electric power of the parallel mode is a total electric power (OI) which is a sum of the rated electric power (OC) of the electric generator 19, and the rated electric power (OD) of the main generator 18.

[0094] A range defined by ODGJK indicates the suppliable thrust range and

suppliable electric power range of the propulsion increasing mode. In the propulsion increasing mode, the main generator 18 supplies the electric power and supplies the electric power to the electric generator 19 which performs the electric motor operation, the electric generator 19 converts the electric power supplied from the main generator 18 into the rotational driving power and supplies the rotational driving power to the propeller 11, and the main engine 17 supplies the thrust of the propeller 11. Therefore, the maximum suppliable thrust of the propulsion increasing mode is a total thrust (OK) which is a sum of the rated thrust (OF) of the electric generator 19 and the rated thrust (OA) of the main engine 17, and the maximum suppliable electric power of the propulsion increasing mode is the rated electric power (OD) of the main generator 18.

[0095] The graph of Fig. 10 indicates the supply capability (the suppliable thrust range and suppliable electric power range) of each of the operation modes in the hybrid propulsion system 10 including one the main engine 17, one main generator 18, and one electric generator 19. Therefore, in a case where the hybrid propulsion system 10 includes the plurality of main engines 17, the plurality of main generators 18, and the plurality of electric generators 19, the supply capability of each of the operation modes is derived based on the number of the devices 17, 18, 19 which are actuated (operating) and the rated outputs of the devices 17, 18, 19 being actuated.

[0096] Next, the operation method (control method) of the hybrid propulsion system 10 of the ship according to Embodiment 6 will be described. Fig. 11 is a flowchart showing an exemplary control of the hybrid propulsion system 10 of the ship according to Embodiment 6. In the flow of Fig. 11, steps S1 to S4 of Fig. 4 are also performed. It should be noted that in the flow of Fig. 11, prior to step S1, the control section 14 causes the memory section 15 to store therein the permissible shifting operation mode combination in which the supply capability of one of the operation modes is lower than that of the other of the operation modes, and one of the operation modes and the other of the operation modes are the operation mode before shifting and the operation mode after shifting, respectively (step S9).

Further, in the flow of Fig. 11, the control section 14 determines whether or not the supply capability is higher than the demand (step S10) after step S1. It should be noted that the permissible shifting operation mode combination may be stored in the

memory section 15 as desired.

[0097] Specifically, as shown in the graph of Fig. 10, the control section 14 derives the suppliable thrust range and suppliable electric power range of each of the operation modes. Then, the control section 14 causes the memory section 15 to store therein the combination of the operation modes in which the suppliable range of the operation mode after shifting is larger than that of the operation mode before shifting, as the permissible shifting operation mode combination (step S9). For example, in the example of Fig. 10, the suppliable range of the parallel mode is larger than that of the shaft generator mode. Therefore, as shown in Fig. 3, the combination of the operation modes in which the shaft generator mode is the operation mode before shifting and the parallel mode is the operation mode after shifting, is automatically stored in the memory section 15 as the permissible shifting operation mode combination. In the example of Fig. 10, the suppliable range of the propulsion increasing mode is larger than that of the electric propulsion mode.

Therefore, as shown in Fig. 3, the combination of the operation modes in which the electric propulsion mode is the operation mode before shifting and the propulsion increasing mode is the operation mode after shifting is automatically stored in the memory section 15 as the permissible shifting operation mode combination.

[0098] The control section 14 obtains the thrust demand and the electric power demand (step S1). The control section 14 determines whether or not the supply capability of the present operation mode is higher than the demand (step S10). When the control section 14 determines that the supply capability of the present operation mode is higher than the demand (step S10: YES), the present operation mode can cover the thrust demand and electric power demand. Therefore, the control section 14 calculates the fuel efficiency (step S2). Then, the control section 14 finds the operation mode with the higher efficiency, among the operation modes whose supply capabilities are higher than the demand. When the control section 14 determines that shifting from the present operation mode to the operation mode with the higher efficiency matches the permissible shifting operation mode combination (step S3: YES), the control section 14 executes shifting of the operation mode (step S4). For example, when the fuel efficiency of the propulsion increasing mode is higher than that of the electric propulsion mode while the ship is operated in

the electric propulsion mode, the control section 14 automatically shifts the electric propulsion mode to the propulsion increasing mode, because the combination of the operation modes in which the electric propulsion mode is shifted to the propulsion increasing mode matches the permissible shifting operation mode combination. Or, when the fuel efficiency of the parallel mode is higher than that of the shaft generator mode while the ship is operated in the shaft generator mode, the control section 14 automatically shifts the shaft generator mode to the parallel mode, because the combination of the operation modes in which the shaft generator mode is shifted to the parallel mode matches the permissible shifting operation mode combination.

[0099] On the other hand, when the control section 14 determines that the supply capability of the present operation mode is lower than the demand (step S10: NO), the present operation mode cannot cover the thrust demand and the electric power demand. Therefore, the control section 14 selects shifting from the present operation mode to the operation mode whose supply capability is higher than the demand, from among the permissible shifting operation mode combinations of the operation mode before shifting and the operation mode after shifting, in which the present operation mode is permitted to be automatically shifted to the operation mode after shifting (step S11). Then, the control section 14 executes shifting of the operation mode (step S4).

[0100] In accordance with the above-described configuration, the control section 14 causes the memory section 15 to store therein the permissible shifting operation mode combinations in which one of the operation modes is permitted to be automatically shifted to the other. This makes it possible to save the operator's trouble of storing the combination of the operation modes in the memory section 15. Therefore, the operator's operation becomes easier.

[0101] Further, the control section 14 selects shifting from the present operation mode to the operation mode whose supply capability is higher than the demand, from among the permissible shifting operation mode combinations in which one of the operation modes (the present operation mode) is permitted to be automatically shifted to the other, which are stored in the memory section 15, and executes shifting of the operation mode. This makes it possible to quickly shift the present operation

mode to the proper operation mode which can cover the demand, even when the supply capability of the hybrid propulsion system 10 becomes insufficient.

[0102] Although in step S11 of Fig. 11, shifting of the operation mode is selected without considering the fuel efficiency, shifting of the operation mode may be selected by considering the fuel efficiency, in a case where there are several options. In this case, when the control section 14 determines that the supply capability of the present operation mode is lower than the demand (step S10: NO), the control section 14 calculates the fuel efficiency (step S2). Then, the control section 14 selects shifting from the present operation mode to the operation mode whose supply capability is higher than the demand and which has the fuel efficiency higher than that of the present operation mode, from among the permissible shifting operation mode combinations in which one of the operation modes (the present operation mode) is permitted to be automatically shifted to the other, which are stored in the memory section 15 (step S11). Then, the control section 14 executes shifting of the operation mode (step S4).

[0103] In the flow of Fig. 11, step S9 may not be performed before step S1. In this case, for example, the operator manually stores in the memory section 15 the combination of the operation modes in which the supply capability of the operation mode after shifting is higher than that of the operation mode before shifting.

[0104] For example, the combination of two operation modes included in the electric propulsion mode, the propulsion increasing mode, the parallel mode, and the shaft generator mode, which is the permissible shifting operation mode combination in which the propulsion increasing mode or the parallel mode is the operation mode after shifting, is stored in the memory section 15. In this case, if the operation mode with the highest fuel efficiency is the propulsion increasing mode or the parallel mode, the control section 14 automatically shifts the present operation mode to the propulsion increasing mode or the parallel mode.

[0105] Further, the steps of Embodiment 1 may be performed in Embodiment 6, and thereby the same advantages as those of Embodiment 1 can be obtained. Further, the hybrid propulsion system 10 according to Embodiment 6 may further include the breaker 27 of Fig. 5, and thereby the same advantages as those of Embodiment 2 can be obtained. Moreover, the hybrid propulsion system 10

according to Embodiment 6 may further include the display section 28 of Fig. 6, and step S5 of Fig. 7, step S6 of Fig. 8, or steps S6 to S8 of Fig. 9 may be performed, in the flow of Fig. 11. Thus, the same advantages as those of Embodiment 3 to Embodiment 5 can be obtained.

[0106] **(Embodiment 7)**

In the hybrid propulsion system 10 of the ship according to Embodiment 7, two arbitrary operation modes are a combination of the operation modes in which the degree of redundancy set in one of the two operation modes is higher than that set in the other of the two operation modes. In this case, in this combination of operation modes, one of the two operation modes is the operation mode before shifting and the other of the two operation modes is the operation mode after shifting. The control section 14 is configured not to cause the memory section 15 to store therein this combination as the permissible shifting operation mode combination.

[0107] Specifically, when the permissible shifting operation mode combination is automatically or manually stored in the memory section 15, the control section 14 sets the degree of redundancy in each of the operation mode before shifting and the operation mode after shifting. The degree of redundancy of each of the operation modes is such that the supply capability can cover the demand when the supply capability of the hybrid propulsion system 10 is degraded due to, for example, a failure of any one of the devices 17, 18, 19.

[0108] The degree of redundancy of each of the operation modes is represented by, for example, a level according to a predetermined rule, or a parallel operation state of the operation mode. As the level according to the predetermined rule, for example, there are a level according to a dynamic positioning class defined by International Maritime Organization, and a level according to a specified rule based on the dynamic positioning class. As the specified rule based on the dynamic positioning class defined by International Maritime Organization, there are rules relating to the dynamic positioning, which are defined by classification societies, for example, DNV GL (Det Norske Veritas), Germanischer Lloyd, and American Bureau of Shipping. In this case, a correspondence between the operation mode and the degree of redundancy is prestored in the memory section 15. Based on this correspondence, the degree of redundancy of the operation mode before shifting and

the degree of redundancy of the operation mode after shifting are derived.

[0109] In a case where the degree of redundancy of each of the operation modes is represented by the parallel operation state, it is derived by the configuration of the operation mode, for example. In this case, the control section 14 derives the degree of redundancy of the operation mode based on the number of devices 17, 18, 19 which are actuated (operating). Specifically, with an increase in the number of devices 17, 18, 19 which are actuated, the number of devices 17, 18, 19 which continue to be actuated is larger, even in a case where a failure occurs in any one of the devices 17, 18, 19. In this state, larger thrust and electric power can be supplied, and the degree of redundancy of the operation mode is higher. From this, the number of devices 17, 18, 19 which are actuated (operating) in each of the operation modes can be assumed as the degree of redundancy of each of the operation modes.

[0110] For example, it is assumed that one device 17, one device 18, and one device 19 are connected to the propeller 11 and the onboard bus 22. In this case, in the parallel mode, two generators which are the main generator 18 and the electric generator 19 which performs the power generation operation are actuated (operating). In contrast, in the shaft generator mode, one generator which is the electric generator 19 which performs the power generation operation is actuated (operating). Thus, since the number of generators which are actuated is larger in the parallel mode than in the shaft generator mode, the degree of redundancy of the electric power of the parallel mode is higher than that of the shaft generator mode. In the propulsion increasing mode, two devices which are the main engine 17 and the electric generator 19 which performs the electric motor operation generate the thrust. In contrast, in the electric propulsion mode, one device which is the electric generator 19 which performs the electric motor operation generates the thrust. Therefore, the number of devices which generate the thrust is larger in the propulsion increasing mode than in the electric propulsion mode. For this reason, the degree of redundancy of the thrust of the propulsion increasing mode is higher than that of the electric propulsion mode.

[0111] In a case where the hybrid propulsion system 10 includes the breaker 27 of Fig. 5, the degree of redundancy of each of the operation modes is decided based on the disconnection (cut-off) or connection of the breaker 27 in addition to the number

of devices 17, 18, 19 which are actuated (operating). For example, as shown in Fig. 5, in a case where the supply system 13 operated in the shaft generator mode and the supply system 13 operated in the external power supply mode are connected to each other via the breaker 27, a failure occurring in the onboard bus 22 negatively affects both of these supply systems 13. Therefore, the degree of redundancy of each of the operation modes during the connection state of the breaker 27 is lower than that during the disconnection state of the breaker 27.

[0112] Then, the control section 14 compares the degree of redundancy set in the operation mode before shifting to the degree of redundancy set in the operation mode after shifting. When the degree of redundancy of the operation mode after shifting is lower than that of the operation mode before shifting, the control section 14 does not cause the memory section 15 to store therein this combination of the operation mode before shifting and the operation mode after shifting, as the permissible shifting operation mode combination.

[0113] The degree of redundancy of the operation mode is determined for each of the thrust and the electric power. Therefore, in a case where the degree of redundancy of the thrust of the operation mode after shifting is lower than that of the thrust of the operation mode before shifting, or the degree of redundancy of the electric power of the operation mode after shifting is lower than that of the electric power of the operation mode before shifting, the control section 14 determines that the degree of redundancy of the operation mode after shifting is lower than that of the operation mode before shifting.

[0114] In accordance with the above-described configuration, in the case of the combination of the operation modes in which the degree of redundancy of one of the operation modes is higher than that of the other of the operation modes, and one of the operation modes and the other operation mode are the operation mode before shifting and the operation mode after shifting, respectively, is not stored in the memory section 15 as the permissible shifting operation mode combination. This makes it possible to prevent the present operation mode from being automatically shifted to the operation mode whose degree of redundancy is lower than that of the present operation mode. As a result, shifting to the safer operation mode can be performed.

[0115] Since the control section 14 derives the degree of redundancy of the operation mode, the operator can save the trouble of deriving the degree of redundancy of the operation mode. Therefore, the operator's operation becomes easier.

[0116] Further, the steps of Embodiment 1 and Embodiment 6 may be performed in Embodiment 7, and thereby the same advantages as those of Embodiment 1 and Embodiment 6 can be obtained. Further, the hybrid propulsion system 10 according to Embodiment 7 may further include the breaker 27 of Fig. 5. Thereby, the same advantages as those of Embodiment 2 can be obtained. Moreover, the hybrid propulsion system 10 according to Embodiment 7 may further include the display section 28 of Fig. 6, and step S5 of Fig. 7, step S6 of Fig. 8, or steps S6 to S8 of Fig. 9 may be performed, in the flow of Fig. 11. As a result, the same advantages as those of Embodiment 3 to Embodiment 5 can be obtained.

[0117] **(Embodiment 8)**

The hybrid propulsion system 10 of the ship according to Embodiment 8 is configured in such a manner that the control section 14 causes the memory section 15 to store therein the permissible shifting operation mode combination, via the console 23 or erases the permissible shifting operation mode combination stored in the memory section 15, via the console 23. Fig. 12 is a block diagram showing the hybrid propulsion system 10 of the ship according to Embodiment 8. As shown in Fig. 12, an input section 29 is connected to the control section 14. For example, a key board or a touch pad is used as the input section 29 and provided on the console 23.

[0118] In response to an operation command input by the input section 29, the control section 14 causes the memory section 15 to store therein the permissible shifting operation mode combination, or erases the permissible shifting operation mode combination from the memory section 15.

[0119] For example, in Embodiment 7, the combination of the operation modes in which the degree of redundancy of the operation mode after shifting is lower than that of the operation mode before shifting is not permitted to be stored in the memory section 15. However, while the ship is traveling on open ocean (outer sea), the ship is less likely to be involved in a collision accident even if the device has a

failure for a short time. Therefore, the degree of redundancy required in the hybrid propulsion system 10 is low. In such a case, the operator inputs the combination of the operation modes in which the degree of redundancy of the operation mode after shifting is lower than that of the operation mode before shifting, by use of the input section 29. In response to the request input by use of the input section 29, the control section 14 causes the memory section 15 to store therein the combination of the operation modes in which the degree of redundancy of the operation mode after shifting is lower than that of the operation mode before shifting, as the permissible shifting operation mode combination.

[0120] In contrast, in a case where the ship is required to hold its position for the purpose of assistance of the oil-drilling rig, the degree of redundancy required in the hybrid propulsion system 10 is high, because the ship maintains the position holding capability, even when a failure occurs in the device. In such a case, by use of the input section 29, the operator erases the permissible shifting operation mode combination in which the degree of redundancy of the operation mode after shifting is lower than the required degree of redundancy of the operation mode, from the permissible shifting operation mode combinations stored in the memory section 15. In response to the request input by use of the input section 29, the control section 14 erases the permissible shifting operation mode combination in which the degree of redundancy of the operation mode after shifting is lower than the required degree of redundancy of the operation mode, from the memory section 15.

[0121] In accordance with the above-described configuration, the permissible shifting operation mode combination can be stored in the memory section 15 or erased from the memory section 15, according to the request input by use of the input section 29. This makes it possible to properly set the operation mode according to the conditions such as the degree of redundancy, which are varied day by day, depending on the content of work of the ship and the external environment conditions, and automatically shift the present operation mode to the proper operation mode.

[0122] Further, the steps of Embodiment 1, Embodiment 6, and Embodiment 7 may be performed in Embodiment 8, and thereby the same advantages as those of Embodiment 1, Embodiment 6, and Embodiment 7 can be obtained. Further, the

hybrid propulsion system 10 according to Embodiment 8 may further include the breaker 27 of Fig. 5. Thereby, the same advantages as those of Embodiment 2 can be obtained. Moreover, the hybrid propulsion system 10 according to Embodiment 8 may further include the display section 28 of Fig. 6, and the steps of Figs. 7 to 9 may be performed. As a result, the same advantages as those of Embodiment 3 to Embodiment 5 can be obtained.

[0123] **(Embodiment 9)**

The hybrid propulsion system 10 of the ship according to Embodiment 9 is configured in such a manner that the control section 14 further causes the memory section 15 to store therein a combination of an operation mode before a failure, a failure state of a device in the operation mode before the failure, and an operation mode after the failure, as a failure shifting operation mode combination. The control section 14 is configured to, in the case of occurrence of the failure, automatically shift the present operation mode to the operation mode after the failure of the failure shifting operation mode combination corresponding to the present operation mode as the operation mode before the failure and the failure state of the device. This failure shifting operation mode combination may be manually stored by the operator by use of the input section 29 of Fig. 12, or pre-stored in a method different from the input section 29.

[0124] Specifically, the failure shifting operation mode combinations are stored in the memory section 15, in addition to the permissible shifting operation mode combinations. Each of the failure shifting operation mode combinations is the combination of the failure state of the device 17, 18, 19, the operation mode before the failure, and the operation mode after the failure. The failure state of the device 17, 18, 19, includes for example, the kind, the number and output of the device 17, 18, 19 having the failure. The kind of the device 17, 18, 19 having the failure includes the main engine 17, the main generator 18, the electric generator 19, the electric motor function of the electric generator 19, and the power generation function of the electric generator 19.

[0125] The operation mode after shifting to which the present operation mode (the operation mode before shifting) is permitted to be automatically shifted in the case of occurrence of the failure is set according to the failure state of the device 17, 18,

19 and the operation mode in the case of occurrence of the failure. For example, in the case of the failure of the electric generator 19, the operation mode after shifting is the operation mode in which the electric generator 19 is de-actuated (stopped), with respect to the operation mode before shifting in which the electric generator 19 is actuated (operating). In this case, as shown in Fig. 3, the propulsion increasing mode is shifted to the machine propulsion mode, or the parallel mode is shifted to the machine propulsion mode.

[0126] Fig. 13 is a flowchart showing an exemplary control of the hybrid propulsion system 10 of the ship according to Embodiment 9. In the flow of Fig. 13, steps S1 to S4 of Fig. 4 according to Embodiment 1 are also performed. It should be noted that in the flow of Fig. 13, the control section 14 determines whether or not there is a failure in the device 17, 18, 19 (step S12) after step S1. When the control section 14 determines that there is a failure in the device 17, 18, 19, the control section 14 selects the operation mode after shifting, based on the failure shifting operation mode combination (step S13).

[0127] Specifically, the control section 14 obtains the thrust demand and the electric power demand (step S1), and monitors whether or not there is a failure in the device 17, 18, 19 (step S12). When the control section 14 determines that there is no failure in the device 17, 18, 19 (step S12: NO), the control section 14 calculates the fuel efficiency (step S2), and shifts the present operation mode to the operation mode with the higher fuel efficiency (step S3: YES, step S4).

[0128] On the other hand, when the control section 14 determines that there is a failure in the device 17, 18, 19 (step S12: YES), the control section 14 selects the failure shifting operation mode combination in which the present failure content matches the failure state and the present operation mode matches the operation mode before shifting (step S13). For example, in a case where the present operation mode is the propulsion increasing mode and the electric generator 19 has a failure, the control section 14 selects the failure shifting operation mode combination in which the propulsion increasing mode is shifted to the machine propulsion mode, as shown in Fig. 3. Then, the control section 14 shifts the present operation mode to the operation mode after shifting of the selected failure shifting operation mode combination (step S4).

[0129] In accordance with the above-described configuration, the combination of the operation modes in which one of the operation modes is permitted to be automatically shifted to the other in the case of occurrence of the failure (failure shifting operation mode combination) is stored in the memory section 15. This makes it possible to automatically shift the present operation mode to the operation mode corresponding to the failure content in the case of occurrence of the failure. As a result, quick shifting to the proper operation mode can be realized.

[0130] Although the shifting of the operation mode is selected without considering the fuel efficiency, in step S13 of Fig. 13, the shifting of the operation mode may be selected considering the fuel efficiency in a case where there are plural portions. In this case, when the control section 14 determines that there is a failure in the device 17, 18, 19 (step S12: YES), the control section 14 calculates the fuel efficiency (step S2). Then, the control section 14 selects the failure shifting operation mode combination in which the present failure content matches the failure state and the present operation mode matches the operation mode before shifting (step S13). Then, the control section 14 shifts the present operation mode to the operation mode after shifting of the selected failure shifting operation mode combination (step S4).

[0131] Further, the steps of Embodiment 1, Embodiment 6, and Embodiment 7 may be performed in Embodiment 9, and thereby the same advantages as those of Embodiment 1, Embodiment 6 and Embodiment 7 can be obtained. Further, when the hybrid propulsion system 10 according to Embodiment 9 may further include the breaker 27 of Fig. 5. Thereby, the same advantages as those of Embodiment 2 can be obtained. Further, the hybrid propulsion system 10 according to Embodiment 9 may further include the display section 28 of Fig. 6, and steps of Figs. 7 to 9 may be performed. As a result, the same advantages as those of Embodiment 3 to Embodiment 5 can be obtained. Moreover, the hybrid propulsion system 10 according to Embodiment 9 may further include the input section 29 of Fig. 12. Thereby, the same advantages as those of Embodiment 8 can be obtained.

[0132] The above-described embodiments may be combined so long as they do not exclude each other.

[0133] Numerous improvements and alternative embodiment of the invention will

be apparent to those skilled in the art in view of the foregoing description.

Accordingly, the description is to be construed as illustrative only, and is provided for the purpose of teaching those skilled in the art the best mode of carrying out the invention. The details of the structure and/or function may be varied substantially without departing from the spirit of the invention.

Industrial Applicability

[0134] A hybrid propulsion system of a ship of the present invention is useful as, for example, a hybrid propulsion system of a ship which is capable of quickly shifting to a proper operation mode.

Reference Signs List

- [0135] 10 hybrid propulsion system
- 11 propeller
- 14 control section
- 15 memory section
- 17 main engine
- 18 main generator
- 19 electric generator
- 22 onboard bus
- 27 display section
- 28 breaker
- 29 input section

Claims

1. A hybrid propulsion system of a ship, comprising:

a main engine which rotates a propeller via a driving power transmission mechanism to supply a thrust;

a main generator which supplies electric power to an onboard bus; and

an electric generator which performs an electric motor operation for rotating the propeller via the driving power transmission mechanism, by the electric power supplied from the main generator to the electric generator via the onboard bus, to supply the thrust, and a power generation operation for generating the electric power by rotational driving power supplied from the main engine to the electric generator via the driving power transmission mechanism and supplying the electric power to the onboard bus,

the hybrid propulsion system being configured to operate via a console, the ship in one of a plurality of operation modes of combinations each including actuation or de-actuation of the main engine, actuation or de-actuation of the main generator, and the electric motor operation, the power generation operation or de-actuation of the electric generator,

the hybrid propulsion system further comprising:

a memory section which stores therein a permissible shifting operation mode combination which is a combination of an operation mode before shifting and an operation mode after shifting, in which the operation mode before shifting is permitted to be automatically shifted to the operation mode after shifting, and

a control section configured to:

calculate a fuel efficiency of each of the operation modes, and obtains an operation mode with the fuel efficiency higher than that of the present operation mode, when a present thrust demand and a present electric power demand fall within a suppliable thrust range in which the thrust can be supplied, and a suppliable electric power range in which the electric power can be supplied, respectively, the suppliable thrust range and the suppliable electric power range being set based on a change characteristic of suppliable electric power with respect to a change in a suppliable thrust, the change characteristic being defined for each of the operation modes, and

automatically shift the present operation mode to the operation mode with the fuel efficiency higher than that of the present operation mode, which is selected from among operation modes after shifting, when a combination of the present operation mode and the obtained operation mode with the fuel efficiency higher than that of the present operation mode matches the permissible shifting operation mode combination.

2. The hybrid propulsion system of the ship according to claim 1, being configured to display on the console, the operation mode with the fuel efficiency higher than that of the present operation mode.

3. The hybrid propulsion system of the ship according to claim 1 or 2, being configured to cause the memory section to store therein the permissible shifting operation mode combination via the console or erase the permissible shifting operation mode combination stored in the memory section via the console.

4. The hybrid propulsion system of the ship according to any one of claims 1 to 3,

wherein the control section is configured to:

when two arbitrary operation modes are a combination of the operation modes in which the suppliable thrust range and the suppliable electric power range of one of the two operation modes are less than the suppliable thrust range and the suppliable electric power range, respectively, of the other of the two operation modes,

automatically store in the memory section, the combination of the two arbitrary operation modes as the permissible shifting operation mode combination in which one of the two operation modes is the operation mode before shifting and the other of the two operation modes is the operation mode after shifting.

5. The hybrid propulsion system of the ship according to any one of claims 1 to 4,

wherein the control section is configured not to:

when two arbitrary operation modes are a combination of the operation modes in which a degree of redundancy set in one of the two operation modes is higher than a degree of redundancy set in the other of the two operation modes, automatically store in the memory section, the combination of the two arbitrary operation modes as the permissible shifting operation mode combination in which one of the two operation modes is the operation mode before shifting and the other of the two operation modes is the operation mode after shifting.

6. The hybrid propulsion system of the ship according to any one of claims 1 to 5, being configured to display an alarm on the console when a degree of redundancy of the operation mode with the fuel efficiency higher than that of the present operation mode is lower than a degree of redundancy of the present operation mode.

7. The hybrid propulsion system of the ship according to claim 5 or 6, wherein the control section is configured to derive the degree of redundancy of the operation mode based on the number of each of the main engine, the main generator, and the electric generator which are actuated.

8. The hybrid propulsion system of the ship according to claim 5 or 6, wherein the control section is configured to derive the degree of redundancy of the operation mode based on a level according to a dynamic positioning class defined by International Maritime Organization, or a level according to a specified rule based on the dynamic positioning class.

9. The hybrid propulsion system of the ship according to any one of claims 1 to 8,

wherein the memory section is configured to further store therein a combination of an operation mode before a failure, a failure state of a device in the operation mode before the failure, and an operation mode after the failure, as a failure shifting operation mode combination, and

wherein the control section is configured to, in a case of occurrence of the

failure, automatically shift the present operation mode to the operation mode after the failure of the failure shifting operation mode combination corresponding to the present operation mode as the operation mode before the failure and the failure state of the device.

10. The hybrid propulsion system of the ship according to any one of claims 1 to 9,

wherein the onboard bus is dividable into a plurality of sections, and the plurality of sections are connected to each other via a breaker, and

wherein each of the operation modes is set based on a combination of the actuation or the de-actuation of the main engine, the actuation or the de-actuation of the main generator, the electric motor operation, the power generation operation, or the de-actuation of the electric generator, and disconnection or connection of the breaker.

11. The hybrid propulsion system of the ship according to any one of claims 1 to 10,

wherein the operation mode includes:

an electric propulsion mode in which the main engine is de-actuated, the main generator is actuated, and the electric generator performs the electric motor operation;

a propulsion increasing mode in which the main engine is actuated, the main generator is actuated, and the electric generator performs the electric motor operation;

a parallel mode in which the main engine is actuated, the main generator is actuated, and the electric generator performs the power generation operation;

a shaft generator mode in which the main engine is actuated, the main generator is de-actuated, and the electric generator performs the power generation operation; and

a machine propulsion mode in which the main engine is actuated, the main generator is actuated, and the electric generator is de-actuated.

12. The hybrid propulsion system of the ship according to claim 11,
wherein the memory section is configured to store therein the permissible shifting operation mode combination in which the electric propulsion mode is the operation mode before shifting and the propulsion increasing mode is the operation mode after shifting, and the permissible shifting operation mode combination in which the shaft generator mode is the operation mode before shifting and the parallel mode is the operation mode after shifting,

wherein the control section is configured to automatically shift the electric propulsion mode to the propulsion increasing mode, when the suppliable thrust of the electric propulsion mode is lower than a present thrust demand or the suppliable electric power of the electric propulsion mode is lower than a present electric power demand, while the ship is operated in the electric propulsion mode, and

wherein the control section is configured to automatically shift the shaft generator mode to the parallel mode, when the suppliable thrust of the shaft generator mode is lower than the present thrust demand or the suppliable electric power of the shaft generator mode is lower than the present electric power demand, while the ship is operated in the shaft generator mode.

13. The hybrid propulsion system of the ship according to claim 11,
wherein the memory section is configured to store therein the permissible shifting operation mode combination of two of the electric propulsion mode, the propulsion increasing mode, the parallel mode, and the shaft generator mode, in which the propulsion increasing mode or the parallel mode is the operation mode after shifting, and

wherein the control section is configured to automatically shift the present operation mode to the propulsion increasing mode or the parallel mode, when the operation mode with the fuel efficiency higher than that of the present operation mode is the propulsion increasing mode or the parallel mode.

14. A control method of a hybrid propulsion system of a ship, comprising:
a main engine which rotates a propeller via a driving power transmission mechanism to supply a thrust;

a main generator which supplies electric power to an onboard bus; and
an electric generator which performs an electric motor operation for rotating the propeller via the driving power transmission mechanism, by the electric power supplied from the main generator to the electric generator via the onboard bus, to supply the thrust, and a power generation operation for generating the electric power by rotational driving power supplied from the main engine to the electric generator via the driving power transmission mechanism and supplying the electric power to the onboard bus,

the hybrid propulsion system being configured to operate via a console, the ship in one of a plurality of operation modes of combinations each including actuation or de-actuation of the main engine, actuation or de-actuation of the main generator, and the electric motor operation, the power generation operation or de-actuation of the electric generator,

the hybrid propulsion system further comprising:

a memory section which stores therein a permissible shifting operation mode combination which is a combination of an operation mode before shifting and an operation mode after shifting, in which the operation mode before shifting is permitted to be automatically shifted to the operation mode after shifting,

the control method comprising:

calculating a fuel efficiency of each of the operation modes, and obtaining an operation mode with the fuel efficiency higher than that of the present operation mode, when a present thrust demand and a present electric power demand fall within a suppliable thrust range in which the thrust can be supplied, and a suppliable electric power range in which the electric power can be supplied, respectively, the suppliable thrust range and the suppliable electric power range being set based on a change characteristic of suppliable electric power with respect to a change in a suppliable thrust, the change characteristic being defined for each of the operation modes, and

automatically shifting the present operation mode to the operation mode with the fuel efficiency higher than that of the present operation mode, which is selected from among operation modes after shifting, when a combination of the present operation mode and the obtained operation mode with the fuel efficiency

higher than that of the present operation mode matches the permissible shifting operation mode combination.