

DESCRIPTION

Title of Invention: METHOD OF CONTROLLING PROPULSION SYSTEM OF MOVABLE BODY

Technical Field

[0001] The present invention relates to a method of controlling a propulsion system of a movable body.

Background Art

[0002] Conventionally known as a movable body propulsion system including a motor generator and a bidirectional power converter is, for example, a hybrid propulsion system of a ship as described in PTL 1. This propulsion system includes a power storage device connected to a DC link of the power converter and utilizes the power storage device for temporary electric power assist. Specifically, when electric power beyond the capacity of a main generator in operation is requested by start-up of a winch and/or the like, electric power is discharged from the power storage device. With this, the electric power is quickly supplied without waiting for the completion of the start-up of an additional generator

Citation List

Patent Literature

[0003] PTL 1: Specification of U.S. Patent No. 8,062,081

Summary of Invention

Technical Problem

[0004] On the other hand, conventional propulsion systems have a problem in which when short-cycle load fluctuation occurs by, for example, propeller racing in stormy weather, the load fluctuation may influence a system frequency and voltage fluctuation, and this may lead to power outage.

[0005] An object of the present invention is to, when short-cycle load fluctuation occurs in a propulsion system of a movable body, suppress an influence of the load fluctuation on an electric power system.

Solution to Problem

[0006] A method of controlling a propulsion system of a movable body according to one aspect of the present invention is a method of controlling a propulsion system of a movable body,

the propulsion system including: a motor generator including a main shaft connected to a driving shaft configured to propel the movable body; a first power converter including an AC terminal connected to an electric power system and a DC terminal connected to a DC link; a second power converter including a DC terminal connected to the DC link and an AC terminal connected to an electrical terminal of the motor generator; and a power storage device connected to the DC link, the propulsion system being configured to receive a mechanical power from the driving shaft to supply electric power to the electric power system and receive the electric power from the electric power system to supply the mechanical power to the driving shaft, the method comprising: subjecting the first power converter to droop control based on a first electric power command value such that a point indicated by a frequency of the electric power system and electric power (hereinafter referred to as “system supplied/received electric power”) supplied or received by the first power converter to or from the electric power system is located on a droop characteristic line showing a relation between a target value of the frequency of the electric power system and a target value of the system supplied/received electric power; and controlling the second power converter based on a second electric power command value such that the electric power converted by the second power converter becomes the second electric power command value, wherein: the first electric power command value is generated by removing a fluctuation component from an original electric power command value, the original electric power command value being a commanded electric power value or an electric power command value generated based on a commanded revolution value of the motor generator; and the second electric power command value is based on the original electric power command value.

[0007] According to the above method, when the motor generator serves as an electric motor, the first power converter converts AC power of the electric power system into DC power, the magnitude of which is based on an electric power command value obtained by removing the fluctuation component from the original electric power command value, and outputs the DC power to the DC link. On the other hand, the second power converter takes out the DC power from the DC link, converts the DC power to the AC power, the magnitude of which is based on the original electric power command value, and outputs the AC power to the motor generator. In this case, the electric power output from the second power converter with respect to the electric power output from the first power converter becomes excessive or deficient in accordance with the fluctuation component of the original electric power command value, and the power storage device is charged or discharged in accordance with the excess or deficiency of the electric power.

[0008] When the motor generator serves as a generator, the second power converter

converts AC generator electric power of the motor generator into the DC power, the magnitude of which is based on the original electric power command value, and outputs the DC power to the DC link. On the other hand, the first power converter takes out the DC power from the DC link, converts the DC power to the AC power, the magnitude of which is based on the electric power command value obtained by removing the fluctuation component from the original electric power command value, and outputs the AC power to the electric power system. In this case, the electric power output from the first power converter with respect to the electric power output from the second power converter becomes excess or deficient in accordance with the fluctuation component of the original electric power command value, and the power storage device is charged or discharged in accordance with the excess or deficiency of the electric power.

[0009] When one of the power converters takes out from the DC link the electric power, the amount of which is equal to the amount of electric power output from the other of the power converters to the DC link, the power storage device does not operate. However, when the amount of electric power output from one of the power converters to the DC link is larger than the amount of electric power taken out by the other of the power converters from the DC link, the voltage of the DC link increases. Therefore, the potential of the DC link becomes higher than that of the power storage device, and the current flows from the DC link to the power storage device. Thus, the power storage device is charged. Further, when the amount of electric power output from one of the power converters to the DC link is smaller than the amount of electric power taken out by the other of the power converters from the DC link, the voltage of the DC link decreases. Therefore, the potential of the DC link becomes lower than that of the power storage device, and the current flows from the power storage device to the DC link. Thus, the power storage device is discharged. As above, only when the supply or reception of the electric power between the first power converter and the second power converter is excessive or deficient, the power storage device is automatically charged or discharged.

[0010] Or, a DC/DC converter may be provided between the DC link and the power storage device and control the voltage of the DC link. In this case, as with the above, only when the supply or reception of the electric power between the first power converter and the second power converter is excessive or deficient, the power storage device is automatically charged or discharged.

[0011] Therefore, the first power converter is subjected to the droop control, so that both a self-sustaining operation and a system interconnected operation can be performed. Further, the first power converter supplies or receives the electric power, the magnitude of which is based on the electric power command value obtained by removing the fluctuation component from the

original electric power command value, to or from the electric power system, and the second power converter supplies or receives a mechanical power corresponding to the electric power, the magnitude of which is based on the original electric power command value, to or from the driving shaft through the motor generator. In addition, a difference between the electric power supplied or received by the first power converter to or from the electric power system and the electric power corresponding to the mechanical power supplied or received by the second power converter to or from the driving shaft through the motor generator is covered by the charging or discharging of the power storage device. With this, even when the original electric power command value fluctuates in a short cycle, the first power converter can stably supply or receive the electric power to or from the electric power system without being influenced by the fluctuation component of the original electric power command value. Further, since the power storage device is charged or discharged in accordance with the fluctuation of the original electric power command value, the second power converter can supply or receive the mechanical power, corresponding to the fluctuation of the original electric power command value, to or from the driving shaft through the motor generator.

[0012] As a result, even when it is necessary to cause the original electric power command value to fluctuate, the influence of the fluctuation on the electric power system can be suppressed.

[0013] The above method of controlling the propulsion system of the movable body may further include: acquiring a SOC (State Of Charge) of the power storage device; calculating a charge/discharge electric power command value such that the SOC falls within a predetermined range by charging or discharging the power storage device; and generating a first charge/discharge electric power command value and a second charge/discharge electric power command value such that a difference between the second charge/discharge electric power command value and the first charge/discharge electric power command value becomes the charge/discharge electric power command value, wherein: the first electric power command value may be generated by adding the first charge/discharge electric power command value and a first propulsion electric power command value generated by removing the fluctuation component from the original electric power command value; and the second electric power command value may be generated by adding the second charge/discharge electric power command value and a second propulsion electric power command value generated based on the original electric power command value.

[0014] According to the above method, the SOC of the power storage device is acquired, and the charge/discharge electric power command value is calculated such that the SOC falls

within the predetermined range. When the SOC is lower than the predetermined range, the charge/discharge electric power command value is calculated such that the SOC falls within the predetermined range by charging the power storage device. In contrast, when the SOC is higher than the predetermined range, the charge/discharge electric power command value is calculated such that the SOC falls within the predetermined range by discharging the power storage device. The first charge/discharge electric power command value and the second charge/discharge electric power command value are generated such that the charge/discharge electric power command value becomes a difference between the second charge/discharge electric power command value and the first charge/discharge electric power command value. The first electric power command value is generated by adding the first charge/discharge electric power command value and the first propulsion electric power command value obtained by removing the fluctuation component from the original electric power command value, and the second electric power command value is generated by adding the second charge/discharge electric power command value and the second propulsion electric power command value generated based on the original electric power command value.

[0015] Therefore, the first electric power command value and the second electric power command value are generated such that the SOC of the power storage device falls within the predetermined range by charging or discharging the power storage device. With this, the power storage device is charged or discharged through the droop control of the first power converter and the electric power control of the second power converter such that the SOC falls within the predetermined range. As a result, the power storage device can be prevented from becoming empty or being overcharged. Here, the SOC may be calculated based on the difference between the second electric power command value and the first electric power command value or may be calculated by a known method, such as by measuring electric power input to and output from the power storage device.

[0016] In the method of controlling the propulsion system of the movable body, the droop characteristic line may be set such that: when the frequency of the electric power system is a standard frequency, the system supplied/received electric power is the first electric power command value; when the frequency of the electric power system is a frequency higher than the standard frequency, the system supplied/received electric power is generator electric power of the motor generator which power is smaller than the first electric power command value or motor electric power of the motor generator which power is larger than the first electric power command value; and when the frequency of the electric power system is a frequency lower than the standard frequency, the system supplied/received electric power is the generator electric

power of the motor generator which power is larger than the first electric power command value or the motor electric power of the motor generator which power is smaller than the first electric power command value.

[0017] According to the above method, the droop characteristic line showing a relation between the target value of the frequency of the electric power system and the system supplied/received electric power of the first power converter can be suitably set for interconnection with the electric power system.

[0018] In the method of controlling the propulsion system of the movable body, the droop control may be performed such that the frequency of the electric power system is controlled to become a frequency calculated from an actual system supplied/received electric power and the droop characteristic line.

[0019] According to the above method, the frequency control of the first power converter can be performed by the droop control.

[0020] In the method of controlling the propulsion system of the movable body, the droop control may be performed such that the system supplied/received electric power is controlled to become electric power calculated from an actual frequency of the electric power system and the droop characteristic line.

[0021] According to the above configuration, the electric power control of the first power converter can be performed by the droop control. Therefore, the self-sustaining operation and the system interconnected operation with the other generator in the electric power system can be performed.

[0022] In the method of controlling the propulsion system of the movable body, the original electric power command value may be an electric power command value of the motor generator, the electric power command value being supplied from an operation console or a dynamic positioning system.

[0023] According to the above method, the original electric power command value is the electric power command value of the motor generator, the electric power command value being supplied from the operation console or the dynamic positioning system. Therefore, while suppressing the influence of the load fluctuation on the electric power system, the electric power control of the motor generator by the second power converter can be promptly performed.

[0024] In the method of controlling the propulsion system of the movable body, the movable body may include a power management system configured to output an electric power generation request to each power source such that electric power supply satisfies an electric power demand, and the original electric power command value may be obtained by adding an

electric power command value, supplied from the power management system, to an electric power command value of the motor generator, the electric power command value of the motor generator being supplied from an operation console or a dynamic positioning system.

[0025] According to the above method, the original electric power command value is obtained by adding the electric power command value, supplied from the power management system, to the electric power command value of the motor generator, the electric power command value of the motor generator being supplied from the operation console or the dynamic positioning system. Therefore, the electric power control of the motor generator by the second power converter can be suitably performed in consideration of power management control of the ship.

[0026] In the method of controlling the propulsion system of the movable body, the original electric power command value may be based on an electric power command value of the motor generator, the electric power command value being obtained by a deviation between an actual revolution of the motor generator and a revolution command value of the motor generator, the revolution command value being supplied from an operation console or a dynamic positioning system.

[0027] According to the above method, the original electric power command value is the electric power command value of the motor generator, the electric power command value being obtained by the deviation between the actual revolution of the motor generator and the revolution command value of the motor generator, the revolution command value of the motor generator being supplied from the operation console or the dynamic positioning system. Therefore, while suppressing the influence of the load fluctuation on the electric power system, the revolution control of the motor generator can be promptly performed.

[0028] In the method of controlling the propulsion system of the movable body, the movable body may include a power management system configured to output an electric power generation request to each power source such that electric power supply satisfies an electric power demand, and the original electric power command value may be obtained by adding an electric power command value, supplied from the power management system, to an electric power command value of the motor generator, the electric power command value of the motor generator being obtained by revolution control performed based on a deviation between an actual revolution of the motor generator and a revolution command value of the motor generator, the revolution command value being supplied from an operation console or a dynamic positioning system.

[0029] According to the above method, the original electric power command value is

obtained by adding the electric power command value, supplied from the power management system, to the electric power command value of the motor generator, the electric power command value of the motor generator being obtained by the deviation between the actual revolution of the motor generator and the revolution command value of the motor generator, the revolution command value being supplied from the operation console or the dynamic positioning system. Therefore, the revolution control of the motor generator by the second power converter can be suitably performed in consideration of the power management control of the ship.

[0030] In the method of controlling the propulsion system of the movable body, removing the fluctuation component from the original electric power command value may be performed by causing the original electric power command value to pass through a low pass filter or a phase compensation filter.

[0031] According to the above method, the fluctuation component is removed from the original electric power command value by causing the original electric power command value to pass through the low pass filter or the phase compensation filter. Therefore, a high frequency component of the original electric power command value is suppressed, and the influence on the electric power system by the fluctuation of the command value supplied to the motor generator can be suppressed.

[0032] The method of controlling the propulsion system of the movable body may further include: detecting a load of the driving shaft; when the load of the driving shaft is larger than a steady-state value, calculating a propulsion electric power correction value such that generator electric power of the motor generator decreases or motor electric power of the motor generator increases; when the load of the driving shaft is smaller than the steady-state value, calculating the propulsion electric power correction value such that the generator electric power of the motor generator increases or the motor electric power of the motor generator decreases; and adding the obtained propulsion electric power correction value to the second electric power command value.

[0033] According to the above method, by adding the propulsion electric power correction value, which is generated in consideration of only the fluctuation component of the load of the driving shaft, to the second electric power command value, the load fluctuation of the main engine can be positively suppressed. Thus, the fuel efficiency improves, and the influence on the system can be suppressed. Therefore, an engine that is weak against the load fluctuation can be applied to the main engine.

Advantageous Effects of Invention

[0034] According to the present invention, in the propulsion system of the movable body,

the deterioration of the fuel efficiency can be suppressed, and the influence of the load fluctuation on the electric power system can be suppressed. Further, an engine that is weak against the load fluctuation can be applied to the main engine.

Brief Description of Drawings

[0035] Fig. 1 is a block diagram schematically showing the configuration of a movable body propulsion system according to Embodiment 1.

Fig. 2A shows a droop characteristic line set when controlling a motor generator that performs a generator operation. Fig. 2B shows a droop characteristic line set when controlling a motor generator that performs a motor operation.

Fig. 3A shows a droop characteristic line in frequency control. Fig. 3B shows a droop characteristic line in electric power control.

Fig. 4 is a block diagram showing a control system of the movable body propulsion system of Fig. 1.

Fig. 5 is a block diagram showing the control system of the movable body propulsion system according to Embodiment 2.

Fig. 6 is a block diagram showing the control system of the movable body propulsion system according to Embodiment 3.

Fig. 7 is a block diagram showing the control system of the movable body propulsion system according to Embodiment 4.

Fig. 8 is a block diagram showing the control system of the movable body propulsion system according to Embodiment 5.

Fig. 9 is a block diagram showing the control system of the movable body propulsion system according to Embodiment 6.

Fig. 10 is a block diagram showing the control system of the movable body propulsion system according to Embodiment 7.

Fig. 11 is a block diagram showing the control system of the movable body propulsion system according to Embodiment 8.

Fig. 12 is a block diagram showing the control system of the movable body propulsion system according to Embodiment 9.

Fig. 13 is a block diagram showing the control system of the movable body propulsion system according to Embodiment 10.

Fig. 14 is a block diagram showing types of movable body propulsion systems to which the present invention is applied.

Description of Embodiments

[0036] Hereinafter, embodiments of the present invention will be explained in reference to the drawings. In the following explanation and drawings, the same reference signs are used for the same or corresponding components, and a repetition of the same explanation is avoided.

[0037] Targets to Which Present Invention is Applied

Targets to which the present invention is applied will be explained before explaining the embodiments of the present invention. Fig. 14 is a block diagram showing the configurations of movable body propulsion systems to which the present invention is applied. To facilitate understanding, Fig. 14 shows a propulsion system of a ship as a typical example of the movable body propulsion system. The configuration of the movable body propulsion system differs depending on the type of the ship. Typical examples of the ship on which the propulsion system of the present invention is mounted include a hybrid ship, a mechanical propulsion ship with a shaft generator, and an electric propulsion ship.

[0038] As shown in Fig. 14A, the hybrid ship includes a movable body propulsion system 10, a main engine 17, and a propulsion unit (typically, a propeller) 11. The movable body propulsion system 10 includes a motor generator 19, a first power converter 25a, a second power converter 25b, and a power storage device 30. The motor generator 19 is mechanically connected to the main engine 17 and the propulsion unit 11 through a power transmission mechanism (for example, a speed reducer) 20. Further, the motor generator 19 is electrically connected to the second power converter 25b, and the second power converter 25b is connected to the first power converter 25a through a DC link. The power storage device 30 is connected to the DC link directly or through a DC/DC converter (not shown). The first power converter 25a is connected to an inboard bus 22. A main generator 18 is connected to the inboard bus 22. In the hybrid ship, the motor generator 19 receives electric power from the main generator 18 through the first power converter 25a and the second power converter 25b to generate a driving force. Then, the motor generator 19 supplies the driving force to the propulsion unit 11 to assist the driving of the propulsion unit 11 by the main engine 17. Further, the motor generator 19 receives motive power from the main engine 17 to generate electric power. Then, the motor generator 19 supplies the electric power to the inboard bus 22 through the second power converter 25b and the first power converter 25a to assist electric power supply to the inboard bus by the main generator 18.

[0039] As shown in Fig. 14B, as compared to the hybrid ship, even if the mechanical propulsion ship with the shaft generator includes a main generator, the main generator is not

interconnected to the motor generator 19, and the motor generator 19 exclusively serves as a generator. Therefore, the propulsion unit 11 is driven exclusively by the main engine 17, and an electric power demand of an electric load connected to the inboard bus 22 is covered by electric power generated by the motor generator 19.

[0040] As shown in Fig. 14C, as compared to the hybrid ship, the electric propulsion ship does not include a main engine, and the motor generator 19 exclusively serves as an electric motor. Therefore, the propulsion unit 11 is driven by the motor generator 19.

[0041] In a general movable body propulsion system, the “movable body” is not especially limited and is only required to be movable. Examples of the movable body include vehicles (such as railcars and cars) and airplanes. Further, the “propulsion unit” is not especially limited and is only required to propel the movable body. Examples of the propulsion unit include wheels and propellers for flight. The “main engine” may be a general “prime mover.” Further, in a mechanical propulsion movable body with a shaft generator, the motor generator 19 may be a mere generator. Further, in an electric propulsion movable body, the motor generator 19 may be a mere electric motor.

[0042] **Operating Modes of Movable Body Propulsion System**

Referring to Figs. 14A to 14C, the propulsion system 10 in a hybrid movable body generally includes four operating modes that are an electric propulsion mode, a propulsion energizing mode, a parallel mode, and a shaft generation mode. The propulsion energizing mode is an operating mode in which the motor generator 19 serves as an electric motor and assists thrust of the main engine 17. The parallel mode is an operating mode in which the motor generator 19 serves as a generator and assists electric power of the main generator 18. The propulsion energizing mode and the parallel mode are operating modes specific to the hybrid movable body. The electric propulsion mode corresponds to an operation of the electric propulsion movable body and is an operating mode in which the hybrid movable body serves as the electric propulsion movable body. In other words, an operation of the propulsion system of the electric propulsion movable body corresponds to the electric propulsion mode of the hybrid movable body.

[0043] The shaft generation mode corresponds to an operation of the mechanical propulsion movable body with the shaft generator and is an operating mode in which the hybrid movable body serves as the mechanical propulsion movable body with the shaft generator. In other words, an operation of the propulsion system of the mechanical propulsion movable body with the shaft generator corresponds to the shaft generation mode of the hybrid movable body.

[0044] In the electric propulsion mode, the motor generator 19 is generally subjected to

revolution control but may be subjected to electric power control. Further, in the propulsion energizing mode, the parallel mode, and the shaft generation mode, generally, the main engine 17 is subjected to the revolution control, and the motor generator 19 is subjected to the electric power control.

[0045] Hereinafter, a control mode in which the motor generator 19 is subjected to the revolution control is referred to as a “revolution control mode”, and a control mode in which the motor generator 19 is subjected to the electric power control is referred to as an “electric power control mode.” To execute the revolution control mode and the electric power control mode, the propulsion system 10 needs to include components dedicated for the respective modes. Further, the revolution control mode and the electric power control mode are switched from one to the other and executed separately. Therefore, explaining the configurations and operations of each control mode at once is easy to understand.

[0046] On this account, hereinafter, embodiments in which the motor generator 19 is subjected to the electric power control and embodiments in which the motor generator 19 is subjected to the revolution control will be separately explained as the embodiments of the present invention.

[0047] **Embodiment 1**

Fig. 1 is a block diagram schematically showing the configuration of the movable body propulsion system 10 according to Embodiment 1. The present embodiment explains the movable body propulsion system 10 configured to subject the motor generator 19 to the electric power control. The movable body propulsion system 10 corresponds to each of the propulsion system of the hybrid movable body including the propulsion energizing mode, the parallel mode, and the shaft generation mode and the propulsion system of the mechanical propulsion movable body with the shaft generator. It should be noted that in the propulsion system of the mechanical propulsion movable body with the shaft generator, the motor generator 19 serves only as a generator.

[0048] As shown in Fig. 1, the movable body includes the propulsion system 10 and the propulsion unit 11. The propulsion system 10 includes the motor generator 19, a power converter 25, the power storage device 30, and a control unit 14. The movable body is provided with one or a plurality of motor generators 19. In the present embodiment, the propulsion system 10 is a propulsion system of a hybrid ship. Therefore, the propulsion system 10 further includes the main engine 17, and the main engine 17 is connected to a driving shaft of the propulsion unit 11 and a main shaft of the motor generator 19 through the power transmission mechanism (for example, a speed reducer) 20 such that motive power can be transmitted

thereamong. The movable body is not especially limited but is a ship in the present embodiment.

[0049] The driving shaft of the propulsion unit 11 is connected to the main shaft of the motor generator 19 of the propulsion system 10 and the main engine 17. The propulsion unit 11 converts the motive power, transmitted from the motor generator 19 and the main engine 17, into the thrust of the movable body. In the present embodiment, the propulsion unit 11 is a propeller configured to propel the ship that is the movable body.

[0050] The motor generator 19 has a motor function of converting AC power to motive power and a generator function of converting motive power to AC power. The main shaft of the motor generator 19 is connected to the main engine 17 and the driving shaft of the propulsion unit 11 such that motive power can be transmitted thereamong, the driving shaft being configured to drive the propulsion unit 11 by a rotational force. For example, the main shaft of the motor generator 19 is coupled to the driving shaft of the propulsion unit 11 and the main engine 17 through the power transmission mechanism 20, such as a speed reducer or a clutch capable of performing engagement and disengagement. An electrical terminal of the motor generator 19 is connected to an electric power system 18 through the bidirectional power converter 25 and is also connected to an electric power load through a bus of the electric power system 18. When the motor generator 19 serves as an electric motor (when the motor generator 19 performs a motor operation), the motor generator 19 converts electric power, input from the electric power system 18 through the power converter 25, into rotational power and transmits the power to the propulsion unit 11. On the other hand, when the motor generator 19 serves as a generator (when the motor generator 19 performs a generator operation), the motor generator 19 converts the rotational power, transmitted from the propulsion unit 11 and the main engine 17, to electric power and outputs the electric power to the bus through the power converter 25.

[0051] The electric power system 18 is constituted by the bus (not shown in Fig. 1), the electric power load (not shown) connected to the bus, and an electric power source such as a generator.

[0052] The bidirectional power converter 25 is a device configured to once convert AC power into DC power and convert the obtained DC power into AC power to change the frequency and voltage of the AC of each of the electric power system 18 and the motor generator 19. One of terminals of the power converter 25 is connected to the electric power system 18, and the other of the terminals thereof is connected to the motor generator 19. Specifically, the power converter 25 includes the first power converter 25a and the second power converter 25b. The first power converter 25a and the second power converter 25b are connected to each other

through a DC link constituted by a pair of wires.

[0053] The first power converter 25a is a system-side power converter and is constituted by, for example, a bidirectional inverter. An AC terminal of the first power converter 25a is connected to the electric power system 18, and a DC terminal thereof is connected to the DC link. The first power converter 25a converts the DC power, input from the DC link, into the AC power and outputs the AC power to the electric power system 18. Further, the first power converter 25a converts the AC power, input from the electric power system 18, into the DC power and outputs the DC power to the DC link.

[0054] The second power converter 25b is a motor generator-side power converter and is constituted by, for example, a bidirectional inverter. A DC terminal of the second power converter 25b is connected to the DC link, and an AC terminal thereof is connected to the motor generator 19. The second power converter 25b converts the AC power, input from the motor generator 19, into the DC power and outputs the DC power to the DC link. Further, the second power converter 25b converts the DC power, input from the DC link, into the AC power and outputs the AC power to the motor generator 19.

[0055] The power storage device 30 is connected to the DC link and smoothes fluctuation of a voltage (DC intermediate voltage) of the DC link. The power storage device 30 is constituted by, for example, a secondary battery or a condenser such as a capacitor.

[0056] The control unit 14 subjects the first power converter 25a to droop control and subjects the second power converter 25b to electric power control to control the motor generator 19. The “droop control” is control in which by constructing in the control unit 14 a model of a governor that controls a generator, characteristics corresponding to the generator are given to the first power converter 25a. Since the first power converter 25a has the characteristics corresponding to the generator, a self-sustaining operation and a system interconnected operation can be seamlessly switched from one to the other.

[0057] Since the “droop control” is a known technology, a detailed explanation thereof is omitted. Regarding the details of the “droop control”, see “G. Marina & E. Gatti, “Large Power PWM IGBT Converter for Shaft Alternator Systems”, 35th Annual IEEE Power Electronics Specialists Conference, 2004,” for example. In the “droop control,” the frequency of the electric power system 18 and the electric power (effective electric power) supplied or received by the first power converter 25a to or from the electric power system 18 are detected by respective sensors (not shown), and the detected results are input to the control unit 14 (to be precise, a below-described droop control portion 145 (see Fig. 4)) and are used for controlling the frequency and the electric power in the droop control.

[0058] According to the present embodiment, in the droop control, a droop characteristic line is set based on a standard frequency of the electric power system 18 and an electric power command value P_c . Then, the frequency of the electric power system 18 or the electric power of the first power converter 25a is controlled to become a target value on the droop characteristic line. The droop characteristic line shows a relation between a target value of the frequency of the electric power system 18 and a target value of “system supplied/received electric power” of the first power converter 25a. It should be noted that the “system supplied/received electric power” denotes the effective electric power of the electric power supplied or received by the first power converter 25a to or from the electric power system 18. In the following explanation regarding the droop characteristic line, electric power supplied by the first power converter 25a to the electric power system in the system supplied/received electric power is referred to as generator electric power, and electric power received by the first power converter 25a from the electric power system in the system supplied/received electric power is referred to as motor electric power. Therefore, positive motor electric power corresponds to negative generator electric power, and positive generator electric power corresponds to negative motor electric power. Further, electric power from the motor generator toward the electric power system is defined as positive electric power, and electric power from the electric power system toward the motor generator is defined as negative electric power.

[0059] Next, a method of setting the droop characteristic line will be explained in reference to Figs. 2A and 2B. Figs. 2A and Fig. 2B are graphs each showing the droop characteristic line. In each graph, a vertical axis shows the frequency of the electric power system 18, and a horizontal axis shows the system supplied/received electric power.

[0060] Fig. 2A shows the droop characteristic line set when the first power converter 25a supplies the electric power to the electric power system. As shown in Fig. 2A, the droop characteristic line when the first power converter 25a supplies the electric power to the electric power system is set such that: when the frequency of the electric power system is a standard frequency F_s , the system supplied/received electric power is the electric power command value P_c ; when the frequency of the electric power system is a frequency higher than the standard frequency F_s , the system supplied/received electric power is the generator electric power of the motor generator, the generator electric power being smaller than the electric power command value P_c ; and when the frequency of the electric power system is a frequency lower than the standard frequency F_s , the system supplied/received electric power is the generator electric power of the motor generator, the generator electric power being larger than the electric power command value P_c .

[0061] Fig. 2B shows a droop characteristic line set when the first power converter 25a receives the electric power from the electric power system. As shown in Fig. 2B, the droop characteristic line when the first power converter 25a receives the electric power from the electric power system is set such that: when the frequency of the electric power system is the standard frequency F_s , the system supplied/received electric power is the electric power command value P_c ; when the frequency of the electric power system is a frequency higher than the standard frequency F_s , the system supplied/received electric power is the motor electric power higher than the electric power command value P_c ; and when the frequency of the electric power system is a frequency lower than the standard frequency F_s , the system supplied/received electric power is the motor electric power lower than the electric power command value P_c .

[0062] As shown in Figs. 2A and 2B, the droop characteristic line is set such that as the frequency of the electric power system 18 decreases, the generator electric power increases, and the motor electric power decreases.

[0063] The droop characteristic line is defined by the standard frequency F_s of the electric power system 18, the electric power command value P_c with respect to the motor generator 19, and an inclination. The standard frequency F_s is predetermined for each electric power system 18. For example, 60 Hz that is a standard frequency of a power supply in a ship or 60 Hz or 50 Hz that is a standard frequency of a power supply in Japan is used as the standard frequency F_s of the electric power system 18. As described below, the electric power command value P_c is set based on operation information input by an operator or the like. The inclination of the droop characteristic line is a predetermined value. Therefore, the droop characteristic line is set so as to pass through a point defined by the standard frequency F_s and the electric power command value P_c . On this account, the droop characteristic line can be changed depending on the electric power command value P_c . Here, the standard frequency F_s is set as the frequency of the electric power system 18. However, the standard frequency F_s is set suitably.

[0064] Next, a droop control method will be explained in reference to Figs. 3A and 3B. Figs. 3A and 3B are graphs each showing the droop characteristic line. As described above, the droop characteristic line is set based on the standard frequency F_s of the electric power system 18 and the electric power command value P_c . Fig. 3A shows a droop characteristic line in frequency control, and Fig. 3B shows a droop characteristic line in electric power control. In each graph, a vertical axis shows the frequency of the electric power system 18, and a horizontal axis shows the system supplied/received electric power.

[0065] An actual frequency (actual value) f of the electric power system 18 and actual system supplied/received electric power (actual value) P are shown by X in each graph. In the

frequency control of Fig. 3A, the actual value f shown by X as the frequency of the electric power system 18 is smaller than a frequency target value f^* obtained from the actual value P shown by X as the system supplied/received electric power and the droop characteristic line. Therefore, the first power converter 25a is controlled such that the actual value f of the frequency of the electric power system 18 becomes the frequency target value f^* . Further, in the electric power control of Fig. 3B, the actual value P shown by X as the system supplied/received electric power is smaller than an electric power target value P^* obtained from the actual value f shown by X as the frequency of the electric power system 18 and the droop characteristic line. Therefore, the first power converter 25a is controlled such that the actual value P of the system supplied/received electric power becomes the electric power target value P^* .

[0066] Next, a specific configuration of the control unit 14 for controlling the motor generator 19 by the “electric power control mode” will be explained in reference to Fig. 4. Fig. 4 is a block diagram showing a control system of the movable body propulsion system 10.

[0067] The control unit 14 is constituted by a processing unit and controls the first power converter 25a and the second power converter 25b. The control unit 14 includes an original electric power command value generating portion 142, a fluctuation component removing portion 144, a droop control portion 145, and an electric power control portion 130. These respective portions of the control unit 14 are functions realized by executing stored programs by the processing unit.

[0068] The original electric power command value generating portion 142 generates an original electric power command value, which is the electric power command value, based on operation information that is input from a lever provided at an operation console 12 and indicates a position of the lever. Here, for example, the original electric power command value generating portion 142 refers to a look-up table, stored in a memory of the processing unit in advance, to set the original electric power command value corresponding to the position of the lever.

[0069] The fluctuation component removing portion 144 removes a fluctuation component from the original electric power command value that is the electric power command value to generate a first electric power command value. In the present embodiment, the fluctuation component removing portion 144 is, for example, a low pass filter or a phase compensation filter.

[0070] The droop control portion 145 subjects the first power converter 25a to the droop control based on the electric power command value output from the fluctuation component removing portion 144. Here, the droop control portion 145 performs the control based on the

first electric power command value such that a point indicated by the frequency of the electric power system 18 and the system supplied/received electric power is located on the droop characteristic line.

[0071] The electric power control portion 130 controls the second power converter 25b based on a second electric power command value, which is the original electric power command value, such that the electric power converted by the second power converter 25b becomes the second electric power command value.

[0072] Next, operations of the movable body propulsion system 10 (i.e., a method of controlling the movable body propulsion system 10) when the motor generator is subjected to the electric power control will be explained in reference to Fig. 4.

[0073] When an operator manipulates the lever of the operation console 12 for adjusting the thrust, the operation information indicating the position of the lever is output to the original electric power command value generating portion 142. Based on a stored look-up table indicating a relation between the operation information and the electric power command value, the original electric power command value generating portion 142 generates the original electric power command value corresponding to the input operation information. Then, the fluctuation component removing portion 144 removes the fluctuation component from the original electric power command value, which is the electric power command value, to generate a first electric power command value P_{c1} and outputs the first electric power command value P_{c1} to the droop control portion 145. The droop control portion 145 sets the droop characteristic line as shown in Fig. 2A or 2B based on the first electric power command value P_{c1} . The frequency target value f^* of the electric power system 18 corresponding to the operation information or the target value P^* of the system supplied/received electric power corresponding to the operation information is determined by the droop characteristic line.

[0074] When the droop control portion 145 subjects the first power converter 25a to the frequency control, as shown in Fig. 3A, the frequency target value f^* is obtained from the actual value P of the system supplied/received electric power and the droop characteristic line. Then, the droop control portion 145 changes a voltage command value or a current command value such that the actual value f of the frequency approaches the frequency target value f^* , and the droop control portion 145 supplies the voltage command value or the current command value to the first power converter 25a.

[0075] Further, when the droop control portion 145 subjects the first power converter 25a to the electric power control, as shown in Fig. 3B, the electric power target value P^* is obtained from the actual value f of the frequency of the electric power system 18 and the droop

characteristic line. Then, the droop control portion 145 changes the voltage command value or the current command value such that the actual value P of the system supplied/received electric power approaches the electric power target value P^* , and the droop control portion 145 supplies the voltage command value or the current command value to the first power converter 25a.

[0076] Next, the operations of the second power converter 25b and the like when the motor generator 19 serves as an electric motor and the operations of the second power converter 25b and the like when the motor generator 19 serves as a generator will be separately explained.

[0077] First, a case where the motor generator 19 serves as the electric motor will be explained. In this case, while the droop control is being performed as described above, the first power converter 25a converts the AC power of the electric power system 18 into the DC power, the magnitude of which is based on the first electric power command value P_{c1} obtained by removing the fluctuation component from the original electric power command value, and outputs the obtained DC power to the power storage device 30 (Fig. 1) of the DC link. On the other hand, the second power converter 25b takes out the DC power from the power storage device 30 of the DC link, converts the DC power into the AC power, the magnitude of which is based on a second electric power command value P_{c2} , and outputs the AC power to the motor generator 19. In this case, the electric power output from the second power converter 25b with respect to the electric power output from the first power converter 25a becomes excessive or deficient in accordance with the fluctuation component of the original electric power command value, and the power storage device 30 is charged or discharged in accordance with the excess or deficiency of the electric power. With this, a propulsive force obtained by adding the driving force of the motor generator 19 to the output of the main engine 17 is transferred to the propulsion unit 11 in accordance with the manipulation of the lever of the operation console 12.

[0078] Next, a case where the motor generator 19 serves as the generator will be explained. In this case, the second power converter 25b converts AC generator electric power of the motor generator 19 into the DC power, the magnitude of which is based on the second electric power command value P_{c2} , and outputs the DC power to the power storage device 30 (Fig. 1) of the DC link. On the other hand, the first power converter 25a takes out the DC power from the power storage device 30 of the DC link, converts the DC power into the AC power, the magnitude of which is based on the first electric power command value P_{c1} obtained by removing the fluctuation component from the original electric power command value, and outputs the AC power to the electric power system 18. In this case, the electric power output from the first power converter 25a with respect to the electric power output from the second power converter 25b becomes excessive or deficient in accordance with the fluctuation

component of the original electric power command value, and the power storage device 30 is charged or discharged in accordance with the excess or deficiency of the electric power. With this, a propulsive force obtained by subtracting the generator electric power of the motor generator 19 from the output of the main engine 17 is transferred to the propulsion unit 11 in accordance with the manipulation of the lever of the operation console 12.

[0079] Even in a case where the voltage of the DC link is controlled by the DC/DC converter provided between the power storage device 30 and the DC link, the power storage device 30 is automatically charged or discharged in the same manner as above only when the electric power transferred between the first power converter 25a and the second power converter 25b becomes excessive or deficient.

[0080] By the above operations in the “electric power control mode,” the first power converter 25a is subjected to the droop control, and the electric power (generator electric power or power consumption (negative generator electric power)) of the motor generator 19 is subjected to feedback control in the droop control. With this, both the self-sustaining operation and the system interconnected operation can be performed. Further, the first power converter 25a supplies or receives the electric power, the magnitude of which is based on the first electric power command value P_{c1} , to or from the electric power system 18, and the second power converter 25b supplies or receives a mechanical power corresponding to the electric power, the magnitude of which is based on the second electric power command value P_{c2} , to or from the driving shaft of the propulsion unit 11 through the motor generator 19. In addition, a difference between the electric power supplied or received by the first power converter 25a to or from the electric power system and the electric power corresponding to the mechanical power supplied or received by the second power converter 25b to or from the driving shaft of the propulsion unit 11 through the motor generator 19 is covered by the charging or discharging of the power storage device 30. With this, even when the original electric power command value fluctuates in a short cycle, the first power converter 25a can stably supply or receive the electric power to or from the electric power system without being influenced by the fluctuation component of the original electric power command value. Further, since the power storage device 30 is charged or discharged in accordance with the fluctuation of the original electric power command value, the second power converter 25b can supply or receive the mechanical power, corresponding to the fluctuation of the original electric power command value, to or from the driving shaft through the motor generator.

[0081] As a result, the load fluctuation of the main engine 17 can be suppressed, and even when it is necessary to cause the original electric power command value to fluctuate, the

influence of the fluctuation on the electric power system can be suppressed. Therefore, the movable body propulsion system 10 can stably operate when the load fluctuation occurs in stormy weather or the like.

[0082] By causing the original electric power command value to pass through the low pass filter or the phase compensation filter, the fluctuation component can be suitably removed from the original electric power command value by the fluctuation component removing portion 144. Therefore, the influence on the electric power system by the fluctuation of the command value supplied to the motor generator can be suitably suppressed.

[0083] The original electric power command value is the electric power command value of the motor generator 19, the electric power command value being supplied from the lever of the operation console 12. Therefore, while suppressing the influence of the load fluctuation on the electric power system, the electric power control of the motor generator 19 by the second power converter 25b can be promptly performed.

[0084] **Embodiment 2**

Next, Embodiment 2 will be explained. The configuration of the movable body propulsion system 10 of the present embodiment is the same as that of Embodiment 1. Hereinafter, explanations of components that are the same as those of Embodiment 1 are omitted, and only components that are different from those of Embodiment 1 will be explained.

[0085] Fig. 5 is a block diagram showing the control system of the movable body propulsion system according to Embodiment 2. As shown in Fig. 5, a control unit 14A includes an input unit (not shown) configured to receive an input from a dynamic positioning system (hereinafter referred to as a "DPS") 150.

[0086] Herein, the DPS 150 is a technology for maintaining a ship at a certain position on the ocean. By confirming the position of the ship through a GPS (global positioning system) or the like and adjusting the propulsive force and propulsion direction of a thruster, a hull can be maintained at a certain position without being moved by wind, tidal current, and/or the like.

[0087] In the present embodiment, the original electric power command value is the electric power command value of the motor generator, the electric power command value being supplied from the DPS 150. Then, the first electric power command value Pc1 is generated by removing the fluctuation component from the original electric power command value, and the second electric power command value Pc2 is generated based on the original electric power command value. With this, the droop control of the first power converter 25a and the electric power control of the second power converter 25b are performed, and the load fluctuation can be suppressed by the charging or discharging of the power storage device 30 in the generator

operation or motor operation of the motor generator 19.

[0088] According to this configuration, the same effects as Embodiment 1 can be obtained, and in addition, the ship can be maintained at a certain position on the ocean by the DPS 150.

[0089] The control unit 14A may include a PCS (Propulsion Control System) 26 (not shown), wherein: the PCS 26, the DPS 150, and the lever operation of the operation console 12 may be switchable; and the electric power command value of the motor generator as the original electric power command value may be supplied from the PCS.

[0090] **Embodiment 3**

Next, Embodiment 3 will be explained. The configuration of the movable body propulsion system 10 of the present embodiment is the same as that of Embodiment 1. Hereinafter, explanations of components that are the same as those of Embodiment 1 are omitted, and only components that are different from those of Embodiment 1 will be explained.

[0091] Fig. 6 is a block diagram showing the control system of the movable body propulsion system according to Embodiment 3. As shown in Fig. 6, the control unit 14B includes: an input unit (not shown) configured to receive an input from a power management system (hereinafter simply referred to as a "PMS") 151; and an adder-subtractor 170.

[0092] The PMS 151 outputs an electric power generation request to each power source such that the electric power supply in the movable body satisfies the electric power demand.

[0093] The electric power system 18 of the ship inputs information to the PMS 151, the information containing a thrust demand, electric power demand, thrust supply capability, and electric power supply capability of the present ship. The PMS 151 compares the thrust demand of the ship with the electric power demand of the ship and also compares the thrust supply capability with the electric power supply capability. Then, the PMS 151 calculates the electric power command value, by which the motor generator 19 is electrically operated or generates electric power, so as to adjust the excess or deficiency of each of the electric power and the thrust in the movable body propulsion system 10.

[0094] The adder-subtractor 170 adds the electric power command value, supplied from the PMS 151, to the electric power command value of the motor generator supplied from the operation console 12 to generate the original electric power command value. Then, the first electric power command value P_{c1} is generated by removing the fluctuation component from the original electric power command value, and the second electric power command value P_{c2} is generated based on the original electric power command value. With this, the droop control of the first power converter 25a and the electric power control of the second power converter 25b are performed, and the load fluctuation can be suppressed by the charging or discharging of the

power storage device 30 in the generator operation or motor operation of the motor generator 19.

[0095] According to this configuration, the excess or deficiency of each of the electric power and the thrust can be adjusted by switching between the motor operation of the motor generator 19 and the generator operation of the motor generator 19. With this, the same effects as Embodiment 1 can be obtained, and in addition, the management of the electric power of the electric power system 18 by the PMS 151 can be realized.

[0096] **Embodiment 4**

Next, Embodiment 4 will be explained. The configuration of the movable body propulsion system 10 of the present embodiment is the same as that of Embodiment 1. Hereinafter, explanations of components that are the same as those of Embodiment 1 are omitted, and only components that are different from those of Embodiment 1 will be explained.

[0097] Fig. 7 is a block diagram showing the control system of the movable body propulsion system according to Embodiment 4. As shown in Fig. 7, a control device 14C includes: an input unit (not shown) configured to receive an input from the DPS 150 and the PMS 151; and the adder-subtractor 170. The present embodiment is different from Embodiment 1 in that the original electric power command value is obtained by adding the electric power command value supplied from the PMS 151 to the electric power command value of the motor generator supplied from the DPS 150. According to this configuration, the same effects as Embodiment 1 can be obtained, and in addition, both automatic driving by the DPS 150 and management of the electric power of the electric power system 18 by the PMS 151 can be realized.

[0098] **Embodiment 5**

Next, Embodiment 5 of the present invention will be explained. The configuration of the movable body propulsion system 10 of the present embodiment is the same as that of Embodiment 1. Hereinafter, explanations of components that are the same as those of Embodiment 1 are omitted, and only components that are different from those of Embodiment 1 will be explained.

[0099] Fig. 8 is a block diagram showing the control system of the movable body propulsion system according to Embodiment 5. As shown in Fig. 8, a control device 14E further includes a SOC calculating portion 155, a charge/discharge electric power command value calculating portion 156, an electric power distribution calculating portion 157, and adder-subtractors 171, 172, and 173.

[0100] The adder-subtractor 173 subtracts the first electric power command value P_{c1} from the second electric power command value P_{c2} and outputs a calculation result to the SOC

calculating portion 155. The SOC calculating portion 155 calculates the SOC based on the input difference between the second electric power command value Pc2 and the first electric power command value Pc1.

[0101] The SOC calculating portion 155 calculates the SOC of the power storage device 30 based on the input difference between the second electric power command value Pc2 and the first electric power command value Pc1 and outputs the SOC to the charge/discharge electric power command value calculating portion 156.

[0102] The charge/discharge electric power command value calculating portion 156 calculates a charge/discharge electric power command value based on the input SOC and outputs the charge/discharge electric power command value to the electric power distribution calculating portion 157. Here, the charge/discharge electric power command value is set to a value by which the power storage device 30 is charged or discharged such that the SOC falls within a predetermined range (for example, 40% to 60%).

[0103] The electric power distribution calculating portion 157 generates a first charge/discharge electric power command value and a second charge/discharge electric power command value in order to distribute the input charge/discharge electric power command value to the droop control portion 145 configured to control the first power converter 25a and the electric power control portion 130 configured to control the second power converter 25b. Then, the electric power distribution calculating portion 157 outputs the first charge/discharge electric power command value to the adder-subtractor 171 and outputs the second charge/discharge electric power command value to the adder-subtractor 172. In the present embodiment, the first charge/discharge electric power command value and the second charge/discharge electric power command value are generated such that the difference between the second charge/discharge electric power command value and the first charge/discharge electric power command value becomes the charge/discharge electric power command value. A value may be set to one of the first charge/discharge electric power command value and the second charge/discharge electric power command value, and the other of the first charge/discharge electric power command value and the second charge/discharge electric power command value may be set to zero.

[0104] The adder-subtractor 171 adds a first propulsion electric power command value and the first charge/discharge electric power command value to generate the first electric power command value Pc1 and outputs the first electric power command value Pc1 to the droop control portion 145, the first propulsion electric power command value being generated by removing the fluctuation component from the original electric power command value by the fluctuation component removing portion 144.

[0105] The adder-subtractor 172 adds a second propulsion electric power command value, generated based on the original electric power command value, and the second charge/discharge electric power command value to generate the second electric power command value Pc2 and outputs the second electric power command value Pc2 to the electric power control portion 130.

[0106] The operations of the second power converter 25b and the like when the motor generator 19 serves as an electric motor in the above configuration and the operations of the second power converter 25b and the like when the motor generator 19 serves as a generator in the above configuration will be separately explained.

[0107] First, a case where the motor generator 19 serves as the electric motor will be explained. In this case, while the droop control is being performed as with Embodiment 1, the first power converter 25a converts the AC power of the electric power system 18 into the DC power, the magnitude of which is based on the first electric power command value Pc1 obtained by removing the fluctuation component from the original electric power command value, and outputs the DC power to the DC link. On the other hand, the second power converter 25b takes out the DC power from the DC link, converts the DC power into the AC power, the magnitude (amount of electric power per unit time) of which is based on the second electric power command value Pc2, and outputs the AC power to the motor generator 19. In this case, the electric power output from the second power converter 25b with respect to the electric power output from the first power converter 25a becomes excessive or deficient in accordance with the fluctuation component of the original electric power command value, and the power storage device 30 is charged or discharged in accordance with the excess or deficiency of the electric power.

[0108] At this time, the SOC of the power storage device 30 is calculated based on the difference between the second electric power command value Pc2 and the first electric power command value Pc1. When the SOC is higher than the predetermined range (for example, when the SOC is not less than 60%), the charge/discharge electric power command value is calculated such that the SOC falls within the predetermined range by discharging the power storage device 30. In contrast, when the SOC is lower than the predetermined range (for example, when the SOC is not more than 40%), the charge/discharge electric power command value is calculated such that the SOC falls within the predetermined range by charging the power storage device 30. Then, the obtained charge/discharge electric power command value is reflected on the first electric power command value Pc1 and the second electric power command value Pc2. When the SOC falls within the predetermined range (for example, when the SOC is 40% to 60%), it is unnecessary to charge or discharge the power storage device 30, so that the

charge/discharge electric power command value is set to zero.

[0109] Next, a case where the motor generator 19 serves as the generator will be explained. In this case, the second power converter 25b converts AC generator electric power of the motor generator 19 into the DC power, the magnitude of which is based on the second electric power command value Pc2, and outputs the DC power to the DC link. On the other hand, the first power converter 25a takes out the DC power from the DC link, converts the DC power into the AC power, the magnitude of which is based on the first electric power command value Pc1 obtained by removing the fluctuation component from the original electric power command value, and outputs the AC power to the electric power system 18. In this case, the electric power output from the first power converter 25a with respect to the electric power output from the second power converter 25b becomes excessive or deficient in accordance with the fluctuation component of the original electric power command value, and the power storage device 30 is charged or discharged in accordance with the excess or deficiency of the electric power. Even when the motor generator 19 serves as the generator, the above SOC control is executed, and the obtained charge/discharge electric power command value is reflected on the first electric power command value Pc1 and the second electric power command value Pc2.

[0110] Therefore, the first electric power command value Pc1 and the second electric power command value Pc2 are generated such that the SOC of the power storage device 30 falls within the predetermined range by charging or discharging the power storage device 30. With this, the power storage device 30 is charged or discharged through the droop control of the first power converter 25a and the electric power control of the second power converter 25b such that the SOC falls within the predetermined range. As a result, the power storage device 30 can be prevented from becoming empty or being overcharged.

[0111] To be specific, according to the present embodiment, the droop control of the first power converter 25a and the electric power control of the second power converter 25b are performed, and the load fluctuation can be suitably suppressed by the charging or discharging of the power storage device 30 while performing the SOC control of the power storage device 30 in the generator operation or motor operation of the motor generator 19.

[0112] **Embodiment 6**

Next, Embodiment 6 will be explained. The configuration of the movable body propulsion system 10 of the present embodiment is the same as that of Embodiment 5. Hereinafter, explanations of components that are the same as those of Embodiment 5 are omitted, and only components that are different from those of Embodiment 5 will be explained.

[0113] Fig. 9 is a block diagram showing the control system of the movable body

propulsion system according to Embodiment 6. As shown in Fig. 9, the present embodiment is different from Embodiment 5 in that the SOC calculating portion 155 measures electric power, input to and output from the power storage device 30, by a known method to calculate the SOC. The present embodiment can obtain the same effects as Embodiment 5.

[0114] **Embodiment 7**

Next, Embodiment 7 will be explained. The present embodiment explains the movable body propulsion system 10 configured to subject the motor generator 19 to the revolution control. The movable body propulsion system 10 corresponds to each of the propulsion system of the hybrid movable body including the electric propulsion mode in addition to the propulsion energizing mode, the parallel mode, and the shaft generation mode and the propulsion system of the electric propulsion movable body. In the propulsion system of the electric propulsion movable body, the motor generator 19 basically serves as an electric motor, but when regenerative braking is performed, the motor generator 19 serves as a generator. The propulsion system 10 of each of the hybrid movable body and the electric propulsion movable body according to the present embodiment includes the components of Embodiments 1 to 6, and only portions different from the components of these embodiments are added. The present embodiment is suitably configured to be able to execute the “electric power control” executed by Embodiments 1 to 6 and the “revolution control” executed by the present embodiment while switching between the electric power control and the revolution control.

[0115] The configuration of the movable body propulsion system 10 of the present embodiment is partially different from that of Embodiment 5. Hereinafter, explanations of components that are the same as those of Embodiment 5 are omitted, and only components that are different from those of Embodiment 5 will be explained.

[0116] The present embodiment is different from Embodiment 5 in that the original electric power command value is based on the electric power command value of the motor generator 19, the electric power command value being obtained by the revolution control that is based on a deviation between an actual revolution of the motor generator 19 and a revolution command value of the motor generator 19, the revolution command value being supplied from the operation console 12. To be specific, Embodiments 1 to 6 explained the configuration that executes the “electric power control” of the motor generator 19, but the present embodiment will explain the configuration that executes the “revolution control” of the motor generator 19.

[0117] Fig. 10 is a block diagram showing the control system of the movable body propulsion system according to Embodiment 7. As shown in Fig. 10, a control device 14F further includes an adder-subtractor 174 and a PID control portion 158. Then, the actual

revolution of the motor generator 19 is input to the control device 14F. Here, the motor generator 19 includes a revolution sensor 19a such as a rotary encoder or a resolver.

[0118] In the present embodiment, the original electric power command value generating portion 142 generates the revolution command value of the motor generator 19 based on the operation information that is input from the lever provided at the operation console 12 and indicates the position of the lever, and the original electric power command value generating portion 142 outputs the revolution command value to the adder-subtractor 174. Here, for example, the original electric power command value generating portion 142 refers to a look-up table, stored in the memory of the processing unit in advance, to set the revolution command value corresponding to the position of the lever.

[0119] The adder-subtractor 174 subtracts the actual revolution, input from the revolution sensor 19a, from the revolution command value of the motor generator 19 input from the original electric power command value generating portion 142 and outputs the obtained result to the PID control portion 158.

[0120] The PID control portion 158 subjects a deviation between the input revolution command value and the actual revolution of the motor generator 19 to proportion processing, integration processing, and differential processing to generate the original electric power command value. The integration processing and the differential processing may be omitted.

[0121] The adder-subtractor 171 adds the first propulsion electric power command value and the first charge/discharge electric power command value to generate the first electric power command value Pc1 and outputs the first electric power command value Pc1 to the droop control portion 145, the first propulsion electric power command value being generated by removing the fluctuation component from the original electric power command value by the fluctuation component removing portion 144.

[0122] The adder-subtractor 172 adds the second propulsion electric power command value, generated based on the original electric power command value, and the second charge/discharge electric power command value to generate the second electric power command value Pc2 and outputs the second electric power command value Pc2 to the electric power control portion 130.

[0123] The droop control portion 145 subjects the first power converter 25a to the droop control based on the electric power command value output from the fluctuation component removing portion 144. Here, the droop control portion 145 performs the same control as the “electric power control mode” of Embodiment 1 and performs the control based on the first electric power command value Pc1 such that a point indicated by the frequency of the electric power system 18 and the system supplied/received electric power is located on the droop

characteristic line.

[0124] The operations of the second power converter 25b and the like when the motor generator 19 serves as an electric motor in the above configuration will be explained.

[0125] When the motor generator 19 serves as the electric motor, the first power converter 25a converts the AC power of the electric power system 18 into the DC power, the magnitude of which is based on the first electric power command value P_{c1} obtained by removing the fluctuation component from the original electric power command value, and outputs the DC power to the DC link. On the other hand, the second power converter 25b takes out the DC power from the DC link, converts the DC power into the AC power, the magnitude of which is based on the second electric power command value P_{c2} , and outputs the AC power to the motor generator 19. The revolution of the motor generator 19 in the motor operation of the motor generator 19 is determined by the load transferred from the propulsion unit 11 and the electric power supplied from the second power converter 25b to the motor generator 19. At this time, the power storage device 30 is charged or discharged in accordance with the excess or deficiency of the electric power output from the second power converter 25b with respect to the electric power output from the first power converter 25a.

[0126] By the above operations in the “revolution control mode,” the first power converter 25a is subjected to the droop control, and the revolution of the motor generator 19 is subjected to the feedback control.

[0127] Further, in the present embodiment, the first electric power command value P_{c1} and the second electric power command value P_{c2} are generated such that the SOC of the power storage device 30 falls within the predetermined range by charging or discharging the power storage device 30. Therefore, the SOC control of Embodiment 5 is also realized.

[0128] Further, the original electric power command value is based on the electric power command value of the motor generator 19, the electric power command value being obtained by the deviation between the actual revolution of the motor generator 19 and the revolution command value of the motor generator 19, the revolution command value being supplied from the lever of the operation console 12. Therefore, while suppressing the influence of the load fluctuation on the electric power system, the revolution control of the motor generator 19 can be promptly performed.

[0129] **Embodiment 8**

Next, Embodiment 8 will be explained. The configuration of the movable body propulsion system 10 of the present embodiment is the same as that of Embodiment 7. Hereinafter, explanations of components that are the same as those of Embodiment 7 are omitted,

and only components that are different from those of Embodiment 7 will be explained.

[0130] Fig. 11 is a block diagram showing the control system of the movable body propulsion system according to Embodiment 8. As shown in Fig. 11, the present embodiment is different from Embodiment 7 (Fig. 10) in that the DPS 150 generates the revolution command value of the motor generator 19 and outputs the revolution command value to the adder-subtractor 174. According to this configuration, the same effects as Embodiment 7 can be obtained, and in addition, the ship can be maintained at a certain position on the ocean by the DPS 150.

[0131] **Embodiment 9**

Next, Embodiment 9 will be explained. The configuration of the movable body propulsion system 10 of the present embodiment is the same as that of Embodiment 7. Hereinafter, explanations of components that are the same as those of Embodiment 7 are omitted, and only components that are different from those of Embodiment 7 will be explained.

[0132] Fig. 12 is a block diagram showing the control system of the movable body propulsion system according to Embodiment 9. As shown in Fig. 12, the present embodiment is different from Embodiment 7 (Fig. 10) in that a control device 14H further includes an adder-subtractor 175 provided at a rear stage of the PMS 151 and the PID control portion 158.

[0133] In the present embodiment, the original electric power command value is obtained by adding the electric power command value, supplied from the PMS 151, to the electric power command value of the motor generator, the electric power command value of the motor generator being obtained by the revolution control performed based on the deviation between the actual revolution of the motor generator 19 and the revolution command value of the motor generator, the revolution command value being supplied from the operation console 12.

[0134] Specifically, the adder-subtractor 175 adds the electric power command value, supplied from the PMS 151, to an output value of the PID control portion 158 to generate the original electric power command value. Then, the first electric power command value Pc1 is generated by removing the fluctuation component from the original electric power command value, and the second electric power command value Pc2 is generated based on the original electric power command value.

[0135] According to this configuration, the excess or deficiency of each of the electric power and the thrust can be adjusted by switching between the motor operation of the motor generator 19 and the generator operation of the motor generator 19. With this, according to the present embodiment, the same effects as Embodiment 7 can be obtained, and in addition, the management of the electric power of the electric power system 18 by the PMS 151 can be

realized.

[0136] In the present embodiment, the revolution command value of the motor generator 19 is supplied through the operation of the lever of the operation console 12. However, as with Embodiment 8, the revolution command value of the motor generator 19 may be supplied from the DPS 150.

[0137] **Embodiment 10**

Next, Embodiment 10 will be explained. The configuration of the movable body propulsion system 10 of the present embodiment is the same as that of Embodiment 7. Hereinafter, explanations of components that are the same as those of Embodiment 7 are omitted, and only components that are different from those of Embodiment 7 will be explained.

[0138] Fig. 13 is a block diagram showing the control system of the movable body propulsion system according to Embodiment 10. As shown in Fig. 13, a control device 14I further includes the adder-subtractor 175, a high-pass filter (HPF) 159, and an amplifier 160. Further, the actual load of the driving shaft of the motor generator 19 is input to the control device 14I from a shaft load sensor 11a provided at the driving shaft of the propulsion unit 11. The shaft load sensor 11a may be configured to directly detect the shaft load using a load measuring device or to indirectly detect the shaft load using a revolution, a motor generator current, a variable pitch propeller blade angle, and/or the like.

[0139] The HPF 159 allows only a high frequency component of a shaft load signal, detected by the shaft load sensor 11a, to pass therethrough and outputs the high frequency component to the amplifier 160. The amplifier 160 adjusts a gain of an output value of the high-pass filter 159 to generate a propulsion electric power correction value and outputs the propulsion electric power correction value to the adder-subtractor 175. The adder-subtractor 175 adds the propulsion electric power correction value, which is the output value of the amplifier 160, to the second electric power command value $Pc2$ and outputs the corrected second electric power command value $Pc2$ to the adder-subtractor 173 and the electric power control portion 130.

[0140] According to the above configuration, the load of the driving shaft of the propulsion unit 11 is detected. When the load of the driving shaft is larger than a steady-state value, the propulsion electric power correction value is calculated such that the generator electric power of the motor generator 19 decreases or the motor electric power of the motor generator 19 increases, and the obtained propulsion electric power correction value is added to the second electric power command value. On the other hand, when the load of the driving shaft is smaller than the steady-state value, the propulsion electric power correction value is calculated such that the

generator electric power of the motor generator 19 increases or the motor electric power of the motor generator 19 decreases, and the obtained propulsion electric power correction value is added to the second electric power command value.

[0141] Therefore, according to the present embodiment, the same effects as Embodiment 7 can be obtained. In addition, by adding the propulsion electric power correction value, which is generated in consideration of only the fluctuation component of the load of the driving shaft, to the second electric power command value, the load fluctuation of the main engine can be positively suppressed. Thus, the fuel efficiency improves, and the influence on the system can be suppressed. Therefore, an engine that is weak against the load fluctuation can be applied to the main engine.

[0142] Other Embodiments

In Embodiments 7 to 10, a component configured to generate and add a charging/discharging command may be omitted.

[0143] From the foregoing explanation, many modifications and other embodiments of the present invention are obvious to one skilled in the art. Therefore, the foregoing explanation should be interpreted only as an example and is provided for the purpose of teaching the best mode for carrying out the present invention to one skilled in the art. The structures and/or functional details may be substantially modified within the scope of the present invention.

Industrial Applicability

[0144] The present invention is useful as a propulsion system of a movable body including a motor generator and a bidirectional power converter.

Reference Signs List

- [0145] 10 movable body propulsion system
- 11 propeller (propulsion unit)
- 11a shaft load sensor
- 12 operation console
- 14 control unit
- 17 main engine
- 18 electric power system (main generator)
- 19 motor generator
- 19a revolution sensor
- 20 speed reducer

22	inboard bus
25	power converter
25a	first power converter
25b	second power converter
30	power storage device
130	electric power control portion
142	original electric power command value generating portion
144	fluctuation component removing portion (Low Pass Filter)
145	droop control portion
150	DPS
151	PMS
155	SOC calculating portion
156	charge/discharge electric power command value calculating portion
157	electric power distribution calculating portion
158	PID control portion
159	HPF
160	amplifier
170 to 175	adder-subtractor

CLAIMS

1. A method of controlling a propulsion system of a movable body,
the propulsion system comprising:
a motor generator including a main shaft connected to a driving shaft configured to propel the movable body;
a first power converter including an AC terminal connected to an electric power system and a DC terminal connected to a DC link;
a second power converter including a DC terminal connected to the DC link and an AC terminal connected to an electrical terminal of the motor generator; and
a power storage device connected to the DC link,
the propulsion system being configured to
receive a mechanical power from the driving shaft to supply electric power to the electric power system and
receive the electric power from the electric power system to supply the mechanical power to the driving shaft,
the method comprising:
subjecting the first power converter to droop control based on a first electric power command value such that a point indicated by a frequency of the electric power system and electric power (hereinafter referred to as “system supplied/received electric power”) supplied or received by the first power converter to or from the electric power system is located on a droop characteristic line showing a relation between a target value of the frequency of the electric power system and a target value of the system supplied/received electric power; and
controlling the second power converter based on a second electric power command value such that the electric power converted by the second power converter becomes the second electric power command value, wherein:
the first electric power command value is generated by removing a fluctuation component from an original electric power command value, the original electric power command value being a commanded electric power value or an electric power command value generated based on a commanded revolution value of the motor generator; and
the second electric power command value is based on the original electric power command value.
2. The method according to claim 1, further comprising:
acquiring a SOC (State Of Charge) of the power storage device;

calculating a charge/discharge electric power command value such that the SOC falls within a predetermined range by charging or discharging the power storage device; and

generating a first charge/discharge electric power command value and a second charge/discharge electric power command value such that a difference between the second charge/discharge electric power command value and the first charge/discharge electric power command value becomes the charge/discharge electric power command value, wherein:

the first electric power command value is generated by adding the first charge/discharge electric power command value and a first propulsion electric power command value generated by removing the fluctuation component from the original electric power command value; and

the second electric power command value is generated by adding the second charge/discharge electric power command value and a second propulsion electric power command value generated based on the original electric power command value.

3. The method according to claim 1, the droop characteristic line is set such that:
when the frequency of the electric power system is a standard frequency, the system supplied/received electric power is the first electric power command value;

when the frequency of the electric power system is a frequency higher than the standard frequency, the system supplied/received electric power is generator electric power of the motor generator which power is smaller than the first electric power command value or motor electric power of the motor generator which power is larger than the first electric power command value; and

when the frequency of the electric power system is a frequency lower than the standard frequency, the system supplied/received electric power is the generator electric power of the motor generator which power is larger than the first electric power command value or the motor electric power of the motor generator which power is smaller than the first electric power command value.

4. The method according to any one of claims 1 to 3, wherein the droop control is performed such that the frequency of the electric power system is controlled to become a frequency calculated from an actual system supplied/received electric power and the droop characteristic line.

5. The method according to any one of claims 1 to 3, wherein the droop control is

performed such that the system supplied/received electric power is controlled to become electric power calculated from an actual frequency of the electric power system and the droop characteristic line.

6. The method according to claim 1 or 2, wherein the original electric power command value is an electric power command value of the motor generator, the electric power command value being supplied from an operation console or a dynamic positioning system.

7. The method according to claim 1 or 2, wherein:
the movable body includes a power management system configured to output an electric power generation request to each power source such that electric power supply satisfies an electric power demand; and

the original electric power command value is obtained by adding an electric power command value, supplied from the power management system, to an electric power command value of the motor generator, the electric power command value of the motor generator being supplied from an operation console or a dynamic positioning system.

8. The method according to claim 1 or 2, wherein the original electric power command value is based on an electric power command value of the motor generator, the electric power command value being obtained by revolution control performed based on a deviation between an actual revolution of the motor generator and a revolution command value of the motor generator, the revolution command value being supplied from an operation console or a dynamic positioning system.

9. The method according to claim 1 or 2, wherein:
the movable body includes a power management system configured to output an electric power generation request to each power source such that electric power supply satisfies an electric power demand; and

the original electric power command value is obtained by adding an electric power command value, supplied from the power management system, to an electric power command value of the motor generator, the electric power command value of the motor generator being obtained by revolution control performed based on a deviation between an actual revolution of the motor generator and a revolution command value of the motor generator, the revolution command value being supplied from an operation console or a dynamic positioning system.

10. The method according to claim 1 or 2, wherein removing the fluctuation component from the original electric power command value is performed by causing the original electric power command value to pass through a low pass filter or a phase compensation filter.

11. The method according to claim 1 or 2, further comprising:
detecting a load of the driving shaft;

when the load of the driving shaft is larger than a steady-state value, calculating a propulsion electric power correction value such that generator electric power of the motor generator decreases or motor electric power of the motor generator increases;

when the load of the driving shaft is smaller than the steady-state value, calculating the propulsion electric power correction value such that the generator electric power of the motor generator increases or the motor electric power of the motor generator decreases; and

adding the obtained propulsion electric power correction value to the second electric power command value.