DESCRIPTION

Title of Invention: POWER SYSTEM OF SHIP

Technical Field

[0001] The present invention relates to a power system of a ship

Background Art

[0002] Various electrically propelled ships mounted with secondary batteries, such as electrically propelled tugboats, have been put into practical use. For example, Patent Literature 1 discloses a ship in which a power storage device is provided on a power feed line of the ship, and thereby the ship is capable of supplying electric power to a propulsion motor and supplying electric power for use in the ship. In recent years, a ship realizing zero emission in a harbor has been put into practical use. The ship is mounted with lithium ion batteries as secondary batteries, and eliminates the necessity of starting the engine while the ship is moored or is being electrically propelled at low speed.

Citation List

Patent Literature

[0003] PTL 1: U.S. Patent Application Publication No. 2009/0156068

Summary of Invention

Technical Problem

[0004] While a ship is travelling or performing particular work, the power load in the ship or the propeller thrust load of the ship temporarily varies to a great degree, which may cause engine tripping, resulting in a risk of power failure in the ship or a risk of the ship becoming non-maneuverable, and may cause the emission of harmful black exhaust from the engine. In order to reduce such risks and emission, it is desired to utilize power storage devices as energy sources to compensate for the load variation. However, in such application, high power is required although the power consumption is small. In this respect, since the power density of secondary batteries is low, the installation of large-sized secondary batteries is necessary, which is unrealistic in view of the installation space of the secondary batteries in the ship and the cost thereof.

[0005] In view of the above, embodiments of the present invention realize, in a power system of a ship, both supplying electric power for use in the ship and compensating for load variation by using power storage devices in a limited space in the ship.

Solution to Problem

[0006] A power system of a ship according to one aspect of the present invention includes: a first power storage device mounted to an onboard bus; a second power storage device mounted to the onboard bus; and a control system configured to control charging/discharging of the first power storage device and the second power storage device. The first power storage device has an energy density higher than that of the second power storage device. The second power storage device has a power density higher than that of the first power storage device. The control system is configured to: as a power generator application, prioritize discharging the first power storage device over discharging the second power storage device, such that base power is continuously supplied to an onboard electrical load connected to the onboard bus; and as a grid stabilization application, prioritize charging/discharging the second power storage device over charging/discharging the first power storage device to compensate for frequency variation or voltage variation of an onboard power grid.

[0007] According to the above aspect, base power, i.e., electric power for operating hotel loads or propelling the ship at a constant speed, is continuously supplied to the onboard electrical load by the first power storage device having a higher energy density, and frequency variation or voltage variation of the onboard power grid is compensated for by the second power storage device having a higher power density. That is, by suitably using the different power storage devices in accordance with the above different applications, even though the total size of the power storage devices is small, these power storage devices can be applied to the power system of the ship.

[0008] The ship may include a propulsion system configured such that a propeller is connected to a main engine and connected to a propulsion motor, a shaft generator, or a propulsion motor generator. The control system may be configured to, as a main engine load variation compensation application, prioritize charging/discharging the second power storage device over charging/discharging the first power storage device to adjust driving of, or electric power generated by, the propulsion motor, the shaft generator, or the propulsion motor generator to reduce load variation of the main engine.

[0009] According to the above embodiment, when load variation of the main engine occurs in the propulsion system, the second power storage device having a higher power density is charged/discharged to adjust the driving of, or electric power generated by, the propulsion motor, the shaft generator, or the propulsion motor generator, and thereby the load variation of the main engine can be suitably reduced.

[0010] A power system of a ship according to another aspect of the present invention includes: a first power storage device mounted to an onboard bus; a second power storage device mounted to the onboard bus; and a control system configured to control charging/discharging of the first power storage device and the second power storage device. The first power storage device has an energy density higher than that of the second power storage device. The second power storage device has a power density higher than that of the first power storage device. The control system: when using at least one of the first power storage device and the second power storage device in at least one of a power generator application for continuously supplying base power to an onboard electrical load connected to the onboard bus and a grid stabilization application for compensating for frequency variation or voltage variation of an onboard power grid, calculates necessary electrical energy for each application based on pre-inputted times for which the respective applications continue or based on operating times of the respective applications, the operating times being estimated by using machine learning technique, and normalizes electrical energy and electric power of necessary charging/discharging for each application to be in a range of 0 to 1; if the normalized electrical energy is greater than the normalized electric power, prioritizes charging/discharging the first power storage device over charging/discharging the second power storage device, and if the normalized electric power is greater than the normalized electrical energy, prioritizes charging/discharging the second power storage device over charging/discharging the first power storage device.

[0011] According to the above aspect, by suitably using the different power storage devices in accordance with the magnitude of electrical energy and the magnitude of electric power of the necessary charging/discharging for each application, even though the total size of the power storage devices is small, these power storage devices can be applied to the power system of the ship.

[0012] The ship may include a propulsion system configured such that a propeller is connected to a main engine and connected to a propulsion motor, a shaft generator, or a propulsion motor generator. The control system may: when using at least one of the first power storage device and the second power storage device in at least one of the power generator application, the grid stabilization application, and a main engine load variation compensation application for adjusting driving of, or electric power generated by, the propulsion motor, the shaft generator, or the propulsion motor generator to reduce load variation of the main engine, obtain the first predetermined value and the second predetermined value for each application, the first predetermined value corresponding to electrical energy of necessary charging/discharging for the application, the second

predetermined value corresponding to electric power of the necessary charging/discharging for the application; if the first predetermined value is greater than the second predetermined value, prioritize charging/discharging the first power storage device over charging/discharging the second power storage device; and if the second predetermined value is greater than the first predetermined value, prioritize charging/discharging the second power storage device over charging/discharging the first power storage device.

[0013] The first power storage device may be a secondary battery, and the second power storage device may be a capacitor. Generally speaking, since charging and discharging of a secondary battery are chemical reactions, the number of available charge/discharge cycles of a secondary battery is less than that of a capacitor. According to the above embodiment, the life of the entire power system can be extended by using the capacitor (the second power storage device), whose power density is higher than that of the secondary battery (the first power storage device), for a short-time charging/discharging application, in which the number of times of charging/discharging is large.

[0014] The power system of the ship may include: a main power generator connected to the onboard bus; and a first power converter connected between the onboard bus and the first power storage device. In the power generator application, the control system may control the first power converter such that when the first power storage device is able to supply, alone or in parallel with the main power generator, electric power at least to the onboard electrical load, if an unexpected output shortage of the main power generator occurs, the electric power is automatically discharged from the first power storage device.

[0015] According to the above embodiment, the redundancy of the onboard power grid can be secured without performing stand-by operation by starting a stand-by generator in addition to the main power generator that is generating electric power. This makes it possible to reduce the fuel consumption and wear on the power generator.

[0016] The power system of the ship may include: a main power generator connected to the onboard bus; and a second power converter connected between the onboard bus and the second power storage device. In the grid stabilization application, the control system may control the second power converter such that charged/discharged power of the second power storage device has a droop characteristic against frequency or voltage, and such that a speed at which frequency variation or voltage variation of the second power storage device follows active power variation is slower than a speed at which frequency variation or voltage variation of the main power generator or the first power storage device follows the active power variation.

[0017] According to the above embodiment, by utilizing droop control characteristics, load variation of the onboard electrical load can be compensated for without detecting the state of the onboard electrical load.

[0018] The power system of the ship may include a second power converter connected between the onboard bus and the second power storage device. In the grid stabilization application, the control system may detect load variation of the onboard electrical load, and may control the second power converter to adjust charged/discharged power of the second power storage device, such that the load variation is reduced.

[0019] According to the above embodiment, charging/discharging of the second power storage device is performed based on the detection of load variation of the electrical load. This makes it possible to actively compensate for load variation of the onboard electrical load. For example, load variation of the electrical load may be directly detected by a power meter(s) installed on the electrical load and/or an electric power source, or may be estimated based on frequency variation or voltage variation of the power grid.

[0020] In the main engine load variation compensation application, the control system may detect load variation of the main engine, and may control the second power converter to adjust charged/discharged power of the second power storage device, such that the load variation is reduced.

[0021] According to the above embodiment, charging/discharging of the second power storage device is performed based on the detection of load variation of the main engine. This makes it possible to actively compensate for load variation of the main engine. For example, load variation of the main engine may be directly detected, or may be estimated based on, for example, rotational speed variation of the main engine.

[0022] The first power storage device or the second power storage device may be connected to the onboard bus of the ship, which is an AC bus, via separate power converters.

[0023] The first power storage device or the second power storage device may be connected to the onboard bus of the ship, which is a DC bus, via separate power converters.

[0024] Alternatively, the ship may include a power converter for driving a motor generator or an electric motor, and the first power storage device or the second power storage device may be connected to a DC link of the power converter via separate power converters.

Advantageous Effects of Invention

[0025] Embodiments of the present invention make it possible to realize, in a power system of a ship, both supplying electric power for use in the ship and compensating for rapid load variation by using power storage devices in a limited space in the ship.

[0026] The above and other aspects, features, and advantages of the present invention will more fully be apparent from the following detailed description of preferred embodiments with accompanying drawings.

Brief Description of Drawings

[0027] Fig. 1 schematically shows the configuration of a ship including a ship power system according to Embodiment 1.

Fig. 2 is a graph schematically showing temporal variation of the power load in the ship and temporal variation of the main engine load of the ship.

Fig. 3 is a block diagram showing the configuration of a control system of Fig. 1.

Fig. 3A is a block diagram showing the configuration of the control system according to one variation of Embodiment 1.

Figs. 4A to 4D show droop characteristic lines that are used for performing droop control of power storage devices in the control system.

Fig. 5 is a block diagram showing the configuration of a control system in a ship power system according to Embodiment 2.

Fig. 6 is a graph showing the performance limit of a first power storage device and the performance limit of a second power storage device.

Fig. 7 schematically shows the configuration of a ship including ship power systems according to first variations.

Fig. 8 schematically shows the configuration of a ship including ship power systems according to second variations.

Fig. 9 schematically shows the configuration of another ship including the above ship power system.

Fig. 10 schematically shows the configuration of yet another ship including the above ship power system.

Fig. 11 schematically shows the configuration of yet another ship including the above ship power system.

Description of Embodiments

[0028] Hereinafter, embodiments of the present invention are described with reference to the drawings. In the drawings, the same or corresponding elements are denoted by the same reference signs, and repeating the same descriptions is avoided below.

[0029] (Embodiment 1)

and 22D. Also, first power storage devices 10B, 10F, 10G and second power storage devices 20A, 20F, 20G are connected via separate power converters 22A, 21B, 21F, 22F, 21G, and 22G to the DC link 51 of the third power converter 23 and the fourth power converter 24, which are provided for driving the motor generator 80.

[0062] Alternatively, the first power storage devices and the second power storage devices may be connected to an onboard DC bus via separate power converters. Fig. 8 schematically shows the configuration of a ship including ship power systems according to variations (H) and (I). It should be noted that (H) and (I) surrounded by enclosing lines in Fig. 8 correspond to the respective variations. In practice, the ship may include one of or both the configurations (H) and (I) surrounded by the enclosing lines. As shown in Fig. 8, first power storage devices 10H and 10I and second power storage devices 20H and 20I are connected to an onboard DC bus 52 via separate power converters 21H, 22H, 21I, and 22I. The main power generator 40 is connected to the onboard DC bus 52 via a zeroth power converter 25.

[0063] In the configuration of Fig. 8, the zeroth power converter 25 and the first power converter 21H may be droop-controlled by a controller (not shown), and the second power converter 22H may be droop-controlled or power-controlled. In this case, the droop characteristic is the relationship between active power and DC voltage, and is set such that the greater the active power, the lower the DC voltage. A value resulting from dividing the difference between the DC voltage at the time of rated load and the DC voltage at the time of no load by a rated DC voltage is defined as a droop rate. Normally, the droop rate is set to the same value for each electric power source. However, as an alternative, the droop rate may be set to a different value for each electric power source as necessary. Each of the zeroth power converter 25 and the first power converter 21H detects the active power, determines a DC voltage target value based on the droop characteristic, and operates by voltage control. Desirably, the speed at which voltage variation follows load variation is set to be the same between both the power converters. Since the operations of the system will be understood by replacing the term “frequency” in Figs. 4A to 4C with “voltage”, the detailed description thereof is omitted herein.

[0064] In the configuration of Fig. 8, the zeroth power converter 25 may be droop-controlled by an attached controller (not shown); the first power converters 21H and 21I may be configured such that the control thereof is instantaneously switchable between constant voltage control and power control; and the second power converters 22H and 22I maybe power-controlled. The control system detects the presence or absence of an electric power source that is being operated on the same bus other than the first power storage devices 10H and 10I.

CLAIMS

1. A power system of a ship, the power system comprising:

a first power storage device mounted to an onboard bus;

a second power storage device mounted to the onboard bus; and

a control system configured to control charging/discharging of the first power storage device and the second power storage device, wherein

the first power storage device has an energy density higher than that of the second power storage device,

the second power storage device has a power density higher than that of the first power storage device, and

the control system is configured to:

as a power generator application, prioritize discharging the first power storage device over discharging the second power storage device, such that base power is continuously supplied to an onboard electrical load connected to the onboard bus; and

as a grid stabilization application, prioritize charging/discharging the second power storage device over charging/discharging the first power storage device in a case where the ship performs work causing load variation to compensate for frequency variation or voltage variation of an onboard power grid.

2. The power system of the ship according to claim 1, wherein

the ship includes a propulsion system configured such that a propeller is connected to a main engine and connected to a propulsion motor, a shaft generator, or a propulsion motor generator, and

the control system is configured to, as a main engine load variation compensation application, prioritize charging/discharging the second power storage device over charging/discharging the first power storage device to adjust driving of, or electric power generated by, the propulsion motor, the shaft generator, or the propulsion motor generator to reduce load variation of the main engine.

3. A power system of a ship, the power system comprising:

a first power storage device mounted to an onboard bus;

a second power storage device mounted to the onboard bus; and

a control system configured to control charging/discharging of the first power storage device and the second power storage device, wherein

the first power storage device has an energy density higher than that of the second power storage device,

the second power storage device has a power density higher than that of the first power storage device, and

the control system:

when using at least one of the first power storage device and the second power storage device in at least one of a power generator application for continuously supplying base power to an onboard electrical load connected to the onboard bus and a grid stabilization application for compensating for frequency variation or voltage variation of an onboard power grid, calculates necessary electrical energy for each application based on pre-inputted times for which the respective applications continue or based on operating times of the respective applications, the operating times being estimated by using machine learning technique, and normalizes electrical energy and electric power of necessary charging/discharging for each application to be in a range of 0 to 1;

if the normalized electrical energy is greater than the normalized electric power, prioritizes charging/discharging the first power storage device over charging/discharging the second power storage device, and

if the normalized electric power is greater than the normalized electrical energy, prioritizes charging/discharging the second power storage device over charging/discharging the first power storage device.

4. The power system of the ship according to claim 3, wherein

the ship includes a propulsion system configured such that a propeller is connected to a main engine and connected to a propulsion motor, a shaft generator, or a propulsion motor generator, and

the control system:

when using at least one of the first power storage device and the second power storage device in at least one of the power generator application, the grid stabilization application, and a

main engine load variation compensation application for adjusting driving of, or electric power generated by, the propulsion motor, the shaft generator, or the propulsion motor generator to reduce load variation of the main engine, calculates necessary electrical energy for each application based on pre-inputted times for which the respective applications continue or based on operating times of the respective applications, the operating times being estimated by using machine learning technique, and normalizes electrical energy and electric power of necessary charging/discharging for each application to be in a range of 0 to 1;

if the normalized electrical energy is greater than the normalized electric power, prioritizes charging/discharging the first power storage device over charging/discharging the second power storage device; and

if the normalized electric power is greater than the normalized electrical energy, prioritizes charging/discharging the second power storage device over charging/discharging the first power storage device.

5. The power system of the ship according to claim 1 or 2, wherein the first power storage device is a secondary battery, and the second power storage device is a capacitor.

6. The power system of the ship according to claim 1 or 2, comprising:

a main power generator connected to the onboard bus; and

a first power converter connected between the onboard bus and the first power storage device, wherein

in the power generator application, the control system controls the first power converter such that when the first power storage device is able to supply, alone or in parallel with the main power generator, electric power at least to the onboard electrical load, if an unexpected output shortage of the main power generator occurs, the electric power is automatically discharged from the first power storage device.

7. The power system of the ship according to claim 1, comprising:

a main power generator connected to the onboard bus; and

a second power converter connected between the onboard bus and the second power storage device, wherein

in the grid stabilization application, the control system controls the second power converter such that charged/discharged power of the second power storage device has a droop characteristic against frequency or voltage, and such that a speed at which frequency variation or voltage variation of the second power storage device follows active power variation is slower than a speed at which frequency variation or voltage variation of the main power generator or the first power storage device follows the active power variation.

8. The power system of the ship according to claim 1, comprising a second power converter connected between the onboard bus and the second power storage device, wherein

in the grid stabilization application, the control system detects load variation of the onboard electrical load, and controls the second power converter to adjust charged/discharged power of the second power storage device, such that the load variation is reduced.

9. The power system of the ship according to any one of claims 1 to 4, wherein

the first power storage device or the second power storage device is connected to the onboard bus of the ship, which is an AC bus, via separate power converters.

10. The power system of the ship according to any one of claims 1 to 4, wherein

the first power storage device or the second power storage device is connected to the onboard bus of the ship, which is a DC bus, via separate power converters.

11. The power system of the ship according to any one of claims 1 to 4, wherein

the ship includes a power converter for driving a motor generator or an electric motor, and

the first power storage device or the second power storage device is connected to a DC link of the power converter via separate power converters.

12. The power system of the ship according to claim 2, comprising:

a main power generator connected to the onboard bus; and

a second power converter connected between the onboard bus and the second power storage device, wherein

in the grid stabilization application, the control system controls the second power converter such that charged/discharged power of the second power storage device has a droop characteristic against frequency or voltage, and such that a speed at which frequency variation or voltage variation of the second power storage device follows active power variation is slower than a speed at which frequency variation or voltage variation of the main power generator or the first power storage device follows the active power variation.

13. The power system of the ship according to claim 2, comprising a second power converter connected between the onboard bus and the second power storage device, wherein

in the grid stabilization application, the control system detects load variation of the onboard electrical load, and controls the second power converter to adjust charged/discharged power of the second power storage device, such that the load variation is reduced.

14. The power system of the ship according to claim 12, wherein

in the main engine load variation compensation application, the control system detects load variation of the main engine, and controls the second power converter to adjust charged/discharged power of the second power storage device, such that the load variation is reduced.

15. The power system of the ship according to claim 13, wherein

in the main engine load variation compensation application, the control system detects load variation of the main engine, and controls the second power converter to adjust charged/discharged power of the second power storage device, such that the load variation is reduced.