

{DESCRIPTION}

{Title of Invention} POWER SUPPLY APPARATUS, CRANE, AND POWER
SUPPLY METHOD

{Technical Field}

{0001}

The present invention relates to a power supply apparatus for a crane, a crane, and a power supply method therefor, the crane transporting containers in, for example, a container yard of a port in which a large number of box-shaped containers (suspension cargoes) are disposed.

{Background Art}

{0002}

In a container yard of a port or other such place, a large number of containers to be loaded into a ship and a large number of containers discharged from a ship are disposed. These containers are stacked on top of each other as multi-stack containers, and the multi-stack containers are arranged for each lane according to a predetermined layout. In each lane, a self-propelled goliath crane such as a rubber tired gantry crane (RTG) is placed so as to straddle the lane. The goliath crane receives/delivers containers from/to trailers and automatic guided vehicles (AGVs) running in the lane, and disposes the containers in the lane.

{0003}

In the crane such as an RTG as described above,

conventionally, an engine generator mounted on the crane generates electric power, and supplies the electric power to a driving motor and a cargo handling motor of the crane.

Further, in the wake of the recent demand for a reduction in environmental load, a hybrid power supply system including a battery in addition to an engine generator is gradually put to practical use. Furthermore, a cable-reel type ground power-feeding system is proposed as a method of promoting the reduction in environmental load. In this system, an engine generator is eliminated, and electric power is supplied from a power feeding source provided on the ground to the crane via a power feeding cable and a cable reel.

{0004}

PTL 1 describes a crane that is driven with power feeding from a commercial power supply and an electric storage apparatus.

In the crane described in PTL 1, a motor is driven in the following manner. If the amount of stored electricity of the electric storage apparatus exceeds a first threshold, the motor is driven by the electric storage apparatus alone in both a high-voltage region and a low-voltage region. If the amount of stored electricity of the electric storage apparatus falls below the first threshold, the motor is driven with the combination use of the electric power from the electric storage apparatus and the electric power from the commercial

power supply. If the amount of stored electricity of the electric storage apparatus falls below a second threshold lower than the first threshold, the motor is driven with only the electric power from the commercial power supply.

{Citation List}

{Patent Literature}

{0005}

{PTL 1} Japanese Unexamined Patent Application, Publication No. 2007-166775

{Summary of Invention}

{Technical Problem}

{0006}

Here, the crane such as an RTG requires the following electric powers to various loads. The electric power required to hoist a suspension cargo is, for example, 150 kW (maximum 270 kW at an overload tolerated rate of 180%), the electric power required for traverse movement of a trolley is, for example, 22 kW (maximum 44 kW at an overload tolerated rate of 200%), and the electric power required when the base load is largest is, for example, approximately 35 kW. That is, the crane requires an electric power of approximately maximum 350 kW in total.

{0007}

In contrast, when a suspension cargo is hoisted down, the crane behaves as a power generator, and regenerates electric

power to the commercial power supply.

{0008}

The balance between such consumption and generation of electric power by the crane is approximately several tens of kilowatts on average, and hence load fluctuation in the crane may be large in some cases.

{0009}

Unfortunately, in the crane described in PTL 1, the electric power that cannot be covered by the electric storage apparatus is supplied from the commercial power supply, and the electric power supplied from the commercial power supply fluctuates depending on circumstances. Accordingly, in the case where the crane described in PTL 1 is applied to an RTG or other such crane, power supply equipment for power feeding from the commercial power supply needs to be provided assuming a high-voltage electric power (for example, AC 6,600 V). Moreover, if electric power fluctuation in the crane is large, further additional power supply equipment needs to be provided.

{0010}

The present invention has been made in view of the above-mentioned circumstances, and therefore has an object to provide a power supply apparatus, a crane, and a power supply method for reducing electric power supplied from a commercial power supply to the crane to thereby enable low-voltage power

transmission.

{Solution to Problem}

{0011}

In order to solve the above-mentioned problem, the power supply apparatus, the crane, and the power supply method according to the present invention adopt the following solutions.

{0012}

That is, a power supply apparatus according to a first aspect of the present invention includes: a storage battery for supplying electric power to an electric power load of a crane, the storage battery being chargeable and dischargeable; a power receiving unit for receiving supply of a predetermined electric power from a commercial power supply; a calculating unit for calculating an electric power difference between the electric power consumed by the electric power load and the electric power supplied from the commercial power supply; and a controlling unit for charging/discharging electric power according to the electric power difference calculated by the calculating unit, to/from the storage battery.

{0013}

According to the first aspect of the present invention, the power supply apparatus according to the first aspect of the present invention includes: the storage battery for supplying the electric power to the electric power load of the

crane, the storage battery being chargeable and dischargeable; and the power receiving unit that receives the supply of the predetermined electric power from the commercial power supply.

That is, the electric power load of the crane is driven with the electric power discharged from the storage battery included in the crane and the electric power supplied from the commercial power supply. The electric power load includes a motor for rotating wheels that serve to move the crane and an auxiliary machine.

{0014}

Then, the calculating unit calculates the electric power difference between the electric power consumed by the electric power load and the electric power supplied from the commercial power supply, and the controlling unit charges/discharges the electric power according to the electric power difference calculated by the calculating unit, to/from the storage battery.

{0015}

As a result, in the power supply apparatus according to the first aspect of the present invention, even if the predetermined electric power supplied from the commercial power supply is set to be low (for example, 45 kW), the electric power discharged from the storage battery assists the electric power supplied from the commercial power supply. Accordingly, the power supply apparatus according to the first

aspect of the present invention reduces the electric power supplied from the commercial power supply to the crane to thereby enable low-voltage power transmission.

{0016}

Further, a power supply apparatus according to a second aspect of the present invention is a power supply apparatus that supplies AC power to an electric power load of a crane including a power generator or a crane from which an existing power generator is eliminated, the power supply apparatus including: a storage battery for supplying electric power to the electric power load, the storage battery being chargeable and dischargeable; a power receiving unit for receiving supply of a predetermined electric power from a commercial power supply; a calculating unit for calculating an electric power difference between the electric power consumed by the electric power load and the electric power supplied from the commercial power supply; a controlling unit for charging/discharging electric power according to the electric power difference calculated by the calculating unit, to/from the storage battery; and a supplying unit for converting DC power from each of the storage battery and the power receiving unit into AC power and supplying the converted power to a power feeding path leading to the electric power load.

{0017}

According to the second aspect of the present invention,

the power supply apparatus according to the second aspect of the present invention supplies the AC power to the electric power load of the crane including the power generator or the crane from which the existing power generator is eliminated, and the power supply apparatus includes: the storage battery for supplying the electric power to the electric power load, the storage battery being chargeable and dischargeable; the power receiving unit that receives the supply of the predetermined electric power from the commercial power supply; and the supplying unit for converting the DC power from each of the storage battery and the power receiving unit into the AC power and supplying the converted power to the power feeding path leading to the electric power load of the crane.

Then, the calculating unit calculates the electric power difference between the electric power consumed by the electric power load and the electric power supplied from the commercial power supply, and the controlling unit charges/discharges the electric power according to the electric power difference calculated by the calculating unit, to/from the storage battery.

{0018}

That is, the power supply apparatus according to the second aspect of the present invention is connected to the power feeding path leading to the electric power load of the existing crane in which electric power is supplied to the

electric power load by the power generator, whereby the electric power load of the existing crane can be driven with the electric power supplied from the storage battery and the commercial power supply.

{0019}

As a result, in the power supply apparatus according to the second aspect of the present invention, even if the predetermined electric power supplied from the commercial power supply is set to be low (for example, 45 kW), the electric power discharged from the storage battery assists the electric power supplied from the commercial power supply. Accordingly, the power supply apparatus according to the second aspect of the present invention reduces the electric power supplied from the commercial power supply to the crane to thereby enable low-voltage power transmission.

{0020}

In addition, in the power supply apparatus having any of the above-mentioned features according to the present invention, the crane is transferrable from one lane to another lane, and the controlling unit charges/discharges the storage battery during transfer of the crane between the lanes, assuming that no electric power is supplied from the commercial power supply.

{0021}

As described above, the storage battery is

charged/discharged during the transfer of the crane between the lanes, assuming that no electric power is supplied from the commercial power supply. Hence, even in the state where no electric power is supplied from the commercial power supply in order to transfer the crane to another lane, the crane can be transferred to another lane. A given storage battery is selected in advance as the storage battery, the given storage battery having an electric power capacity that is large enough to cover the electric power consumed during the transfer of the crane between the lanes.

{0022}

In addition, the power supply apparatus having any of the above-mentioned features according to the present invention may have a configuration in which the electric power supplied from the commercial power supply is set to be variable within a range equal to or less than the predetermined electric power.

{0023}

According to this configuration, the electric power supplied from the commercial power supply is set to be variable within the range equal to or less than the predetermined electric power. Hence, in the case where the amount of electric power consumed by the electric power load is small, the electric power supplied from the commercial power supply can be further reduced.

{0024}

In addition, in the power supply apparatus having this configuration, the controlling unit changes the electric power supplied from the commercial power supply, on a basis of a history of a charge state of the storage battery.

{0025}

As described above, the electric power supplied from the commercial power supply is changed on the basis of the history of the charge state of the storage battery. Hence, in the case where the amount of charge in the storage battery is large, the electric power supplied from the commercial power supply can be further reduced.

{0026}

In addition, in the power supply apparatus having this configuration, the controlling unit changes the electric power supplied from the commercial power supply, on a basis of a history of the electric power supplied to the electric power load.

{0027}

As described above, the electric power supplied from the commercial power supply is changed on the basis of the history of the electric power supplied to the electric power load. Hence, in the case where the amount of electric power consumed by the electric power load is small, the electric power supplied from the commercial power supply can be further

reduced.

{0028}

In addition, in the power supply apparatus having any of the above-mentioned features according to the present invention, the crane changes acceleration in a hoisting operation in which a suspension cargo is hoisted, to thereby perform the hoisting operation so as to suppress the electric power consumed by the electric power load, and an electric power capacity of the storage battery is based on the electric power suppressed through the hoisting operation.

{0029}

The consumed electric power becomes excessive in some cases in accordance with the acceleration of the hoisting operation of the crane. Hence, the acceleration of the hoisting operation is changed, whereby excessive consumed electric power is suppressed from occurring. As a result, according to the present invention, the electric power capacity of the storage battery can be determined on the basis of the electric power suppressed through the hoisting operation, and the storage battery having a smaller electric power capacity can be adopted.

{0030}

Further, a crane according to a third aspect of the present invention includes: the power supply apparatus having any of the above-mentioned features; and an electric power

load that is driven with electric power supplied from the power supply apparatus.

{0031}

According to the third aspect of the present invention, because the power supply apparatus having any of the above-mentioned features is provided, even if the predetermined electric power supplied from the commercial power supply is set to be low (for example, 45 kW), the electric power discharged from the storage battery assists the electric power supplied from the commercial power supply. Accordingly, the crane according to the third aspect of the present invention reduces the electric power supplied from the commercial power supply to the crane to thereby enable low-voltage power transmission.

{0032}

Further, a power supply method according to a fourth aspect of the present invention is a power supply method for supplying electric power to an electric power load of a crane, the crane including: a storage battery for supplying electric power to the electric power load, the storage battery being chargeable and dischargeable; and a power receiving unit for receiving supply of a predetermined electric power from a commercial power supply, the power supply method including: a first stage of calculating an electric power difference between the electric power consumed by the electric power load

and the electric power supplied from the commercial power supply; and a second stage of charging/discharging electric power according to the electric power difference calculated in the first stage, to/from the storage battery.

{0033}

According to the fourth aspect of the present invention, in the power supply method according to the fourth aspect of the present invention, even if the predetermined electric power supplied from the commercial power supply is set to be low (for example, 45 kW), the electric power discharged from the storage battery assists the electric power supplied from the commercial power supply. Accordingly, the power supply method according to the fourth aspect of the present invention reduces the electric power supplied from the commercial power supply to the crane to thereby enable low-voltage power transmission.

{0034}

Further, a power supply method according to a fifth aspect of the present invention is a power supply method for a power supply apparatus that supplies AC power to an electric power load of a crane including a power generator or a crane from which an existing power generator is eliminated, the power supply apparatus including: a storage battery for supplying electric power to the electric power load of the crane, the storage battery being chargeable and dischargeable;

a power receiving unit for receiving supply of a predetermined electric power from a commercial power supply; and a supplying unit for converting DC power from each of the storage battery and the power receiving unit into AC power and supplying the converted power to a power feeding path leading to the electric power load, the power supply method including: a first stage of calculating an electric power difference between the electric power consumed by the electric power load and the electric power supplied from the commercial power supply; and a second stage of charging/discharging electric power according to the electric power difference calculated in the first stage, to/from the storage battery.

{0035}

According to the fifth aspect of the present invention, the power supply apparatus having any of the above-mentioned features according to the present invention is connected to the power feeding path of the existing crane in which electric power is supplied to the electric power load by the power generator, whereby the electric power load of the existing crane can be driven with the electric power supplied from the storage battery and the commercial power supply.

As a result, in the power supply method according to the fifth aspect of the present invention, even if the predetermined electric power supplied from the commercial power supply is set to be low (for example, 45 kW), the

electric power discharged from the storage battery assists the electric power supplied from the commercial power supply. Accordingly, the power supply method according to the fifth aspect of the present invention reduces the electric power supplied from the commercial power supply to the crane to thereby enable low-voltage power transmission.

{Advantageous Effects of Invention}

{0036}

The present invention produces an excellent effect of reducing electric power supplied from a commercial power supply to a crane to thereby enable low-voltage power transmission.

{Brief Description of Drawings}

{0037}

{Fig. 1} Fig. 1 is a perspective view illustrating a crane according to a first embodiment of the present invention.

{Fig. 2} Fig. 2 is a diagram schematically illustrating an electrical configuration of the crane according to the first embodiment of the present invention.

{Fig. 3} Fig. 3 is a block diagram illustrating a detailed configuration of a power supply apparatus according to the first embodiment of the present invention.

{Fig. 4} Fig. 4 is a graph showing a temporal change in

electric power consumed by electric power loads of the crane according to the first embodiment of the present invention.

{Figs. 5} Figs. 5 are graphs each showing a change in hoisting speed or consumed electric power in a hoisting operation according to a third embodiment of the present invention.

{Fig. 6} Fig. 6 is a diagram schematically illustrating an electrical configuration of a crane according to a fourth embodiment of the present invention.

{Description of Embodiments}

{0038}

Hereinafter, embodiments of a power supply apparatus, a crane, and a power supply method for a crane according to the present invention are described with reference to the drawings.

{0039}

[First Embodiment]

Hereinafter, a first embodiment of the present invention is described.

{0040}

Fig. 1 illustrates a crane 1 according to the first embodiment.

Fig. 1 illustrates the crane 1 that is set in a moving direction X on a lane R. The crane 1 is configured as an electric crane with a ground power-feeding system that is operated with electric power supplied from a power feeding box

31 set on the ground, and does not include an engine generator. The crane 1 includes a power feeding cable reel apparatus for the crane (hereinafter, simply referred to as "cable reel apparatus") 2.

{0041}

The crane 1 is a so-called rubber tired gantry crane (RTG), which is a self-propelled goliath crane including a plurality of wheels (rubber tires) 3. The crane 1 is placed so as to straddle the lane R. On the lane R, a plurality of containers (hereinafter, referred to as "suspension cargos") are stacked on top of each other as multi-stack suspension cargos according to a predetermined layout. The crane 1 moves in the longitudinal direction of the lane R (moving direction X).

{0042}

The crane 1 includes four moving apparatuses 5 respectively provided to leg parts 11, and each moving apparatus 5 includes four wheels 3. The drive of the moving apparatus 5 is controlled by a movement controlling apparatus 7. The moving apparatus 5 is provided with an automatic steering sensor 6. The automatic steering sensor 6 detects magnetism from a magnetic guide line 15 laid in the longitudinal direction of the lane R. With this configuration, the crane 1 can be automatically moved straight in the moving direction X.

{0043}

The moving apparatuses 5 that are adjacent in the moving direction X corresponding to the left-right direction are coupled to each other by a lower beam 9, and the movement controlling apparatus 7 is set on the lower beam 9. Note that the left-right direction refers to the moving direction of the crane 1, and the front-back direction refers to the moving direction (traverse direction Y) of a trolley 20. These definitions are based on the attitude of an operator in an operator's room 22 set to the trolley 20.

{0044}

A bay sensor 8 facing downward is provided in the center of the lower beam 9. The bay sensor 8 detects magnetism from magnets 16 laid for each bay, and the bay is a unit in the left-right direction of the disposed suspension cargos. With this configuration, the crane 1 can be stopped at a desired bay.

Posts 10 are respectively provided in a standing manner to both ends of the lower beam 9. The upper end of each post 10 is coupled by a girder 12 to the upper end of the corresponding post 10 that is provided in a standing manner to the lower beam 9 on the opposite side.

{0045}

The two girders 12 are provided in parallel with each other in the left-right direction, and the trolley 20 moves on

the girders 12 in the front-back direction (traverse direction Y). The trolley 20 is provided with the operator's room 22, and the operator stands by in the operator's room 22 to operate the crane 1.

{0046}

A spreader (suspension device) 24 is suspended from the trolley 20, and the suspension cargo is gripped by the spreader 24 to be suspended. Specifically, twist lock pins (not illustrated) each having an enlarged head part at the leading end are respectively provided to four corners of the spreader 24 so as to protrude downward, and the enlarged head parts of the twist lock pins are respectively inserted into holes formed at four corners of the upper surface of the suspension cargo, are rotated, and thus are engaged therewith. The suspension cargo is suspended by the spreader 24 in this manner, to be thereby moved to a desired position in accordance with the movement of the trolley 20.

{0047}

The crane 1 includes a power supply apparatus 40 (see Figs. 2 and 3) including a battery 42 (storage battery) and a charging/discharging apparatus 48 to be described later. The battery 42 stores electric power that is supplied from the power feeding box 31 fixedly set on the ground via a power feeding cable 33 and a cable reel 35. The power feeding box 31 supplies a low-voltage electric power of, for example, AC

460 V.

{0048}

Because the power feeding cable 33 is designed to supply a low voltage of AC 460 V, the diameter of the power feeding cable 33 is smaller than that of a conventional power feeding cable designed to supply a high voltage of, for example, AC 6,600 V. Consequently, the diameter of the cable reel 35 is also smaller than that of a conventional cable reel, leading to the downsizing thereof. The cable reel 35 thus downsized is set so as to protrude in the moving direction X of the crane 1.

{0049}

The cable reel apparatus 2 including the cable reel 35 is detachably attached to the crane 1. In addition, as illustrated in Fig. 1, a plurality of the cable reel apparatuses 2 can be provided to one crane 1. Then, the position of the cable reel apparatus 2 can be changed in accordance with the position of the power feeding box 31.

{0050}

Fig. 2 is a diagram schematically illustrating an electrical configuration of the crane 1 according to the first embodiment.

{0051}

The crane 1 includes the power supply apparatus 40 that supplies (feeds) electric power to electric power loads, the

power supply apparatus 40 including: a PWM converter 41 that receives supply of a predetermined electric power from a commercial power supply and supplies the electric power to the electric power loads; and the battery 42 for supplying the electric power to the electric power loads, the battery 42 being chargeable and dischargeable.

{0052}

In the power supply apparatus 40, AC power is fed from the power feeding box 31 as power supply equipment on the ground, the AC power is converted into DC power by the PWM converter 41, and the converted power is fed to load driving inverters 43A to 43F respectively connected to the corresponding electric power loads.

In the power feeding box 31, AC power is received from the commercial power supply by a high-voltage power receiving board 44, the received AC power is converted into a predetermined level of AC power (for example, 6,600 V is converted into 460 V) by a transformer 45, and the converted power is fed to the power supply apparatus 40.

{0053}

The PWM converter 41 is connected to the power feeding cable 33 connected to the power feeding box 31, via a power feeding connector 46 and a cable reel 47, whereby the AC power fed from the power feeding box 31 is converted into the DC power.

{0054}

The power supply apparatus 40 also includes the charging/discharging apparatus (DC/DC converter) 48, which enables a predetermined level of DC power to be charged/discharged to/from the battery 42, whereby the power is fed to the load driving inverters 43A to 43F respectively connected to the corresponding electric power loads.

{0055}

The crane 1 includes, as the electric power loads, a traverse motor 49A for traverse movement of the trolley 20, motors 49B to 49E for rotating the wheels 3, a motor 49F for turning, a hoist motor 49G for hoisting a suspension cargo, and an auxiliary machine 50.

When the hoisted suspension cargo is lowered, the hoist motor 49G functions as a power generator to thereby generate electric power.

{0056}

In the following description, in the case where the respective motors 49 are discriminated from one another, any of A to G is attached to the end of the reference sign, and in the case where the respective motors 49 are not discriminated from one another, A to G are omitted. Similarly, in the case where the respective load driving inverters are discriminated from one another, any of A to F is attached to the end of the reference sign, and in the case where the respective load

driving inverters 43 are not discriminated from one another, A to F are omitted.

{0057}

Then, the DC power from the power supply apparatus 40 is converted into the AC power by each of the load driving inverters 43, and the load driving inverters 43 respectively feed the converted power to the corresponding motors 49 and auxiliary machine 50.

{0058}

In addition, the electric power that is not consumed by the electric power loads is consumed by a resistor 51.

{0059}

Fig. 3 is a block diagram illustrating a detailed configuration of the power supply apparatus 40.

{0060}

The power supply apparatus 40 includes a charge/discharge controlling apparatus 53 in addition to the PWM converter 41, the battery 42, and the charging/discharging apparatus 48.

{0061}

The charging/discharging apparatus 48 controls the charge/discharge of the battery 42 on the basis of a charge/discharge power command value P_T outputted from the charge/discharge controlling apparatus 53, and outputs a charge/discharge power feedback value P_B of the battery 42 to the charge/discharge controlling apparatus 53.

{0062}

The charge/discharge controlling apparatus 53 calculates the electric power difference between the electric power consumed by the electric power loads and the electric power supplied from the commercial power supply.

For example, the charge/discharge controlling apparatus 53 receives, from the PWM converter 41, a value (input electric power feedback value P_I) indicating the input electric power, and receives, from each of the load driving inverters 43, a value (load consumed electric power feedback value P_L) indicating the electric power consumed by the corresponding electric power load. The load consumed electric power P_L is calculated from the total sum (kW) of the product of voltages V and currents I from the load driving inverters 43, and represents load fluctuation as a disturbing element.

{0063}

An input electric power target value $P_{I\text{target}}$ is a predetermined value, that is, a fixed value.

{0064}

Fig. 4 is a graph showing a temporal change in the electric power consumed by the electric power loads.

In Fig. 4, the horizontal axis represents the temporal change, and the vertical axis represents the electric power. Fig. 4 shows the temporal change in the consumed electric power consumed by the electric power loads. When the electric

power is positive, the electric power loads are consuming the electric power. On the other hand, when the electric power is negative, the crane 1 is hoisting down a suspension cargo, and the hoist motor 49G is generating electric power.

{0065}

Then, a straight line A represents the average value of the consumed electric power, and in the first embodiment, the input electric power target value $P_{I\text{target}}$ is set to this average value (for example, 45 kW) by way of example.

{0066}

Then, as shown in Expression (1), the sum of the input electric power target value $P_{I\text{target}}$ and the charge/discharge power command value P_T is equal to the load consumed electric power P_L . Accordingly, as shown in Expression (2), the charge/discharge power command value P_T is calculated by the charge/discharge controlling apparatus 53 as a value indicating the electric power difference between the electric power consumed by the electric power loads and the electric power supplied from the commercial power supply.

$$P_{I\text{target}} + P_T = P_L \cdots (1)$$

$$P_T = P_L - P_{I\text{target}} \cdots (2)$$

{0067}

The charge/discharge power command value P_T calculated on the basis of Expression (2) is outputted to the charging/discharging apparatus 48.

The charging/discharging apparatus 48 charges/discharges the electric power according to the charge/discharge power command value P_T to/from the battery 42.

Specifically, the charging/discharging apparatus 48 performs such charge/discharge control that the battery 42 is discharged in the case where the charge/discharge power command value P_T is positive, whereas the battery 42 is charged in the case where the charge/discharge power command value P_T is negative.

{0068}

As described above, the charge/discharge power command value P_T outputted from the charge/discharge controlling apparatus 53 to the charging/discharging apparatus 48 is based on the load consumed electric power P_L outputted from each of the load driving inverters 43, and the charge/discharge of the battery 42 is feedback controlled. Accordingly, if any delay in control occurs, an influence of the delay is compensated on the basis of Expressions (3) and (4) given below.

{0069}

$$\Delta P_T = K \times (P_{I\text{target}} - P_I) \cdots (3)$$

In Expression (3), K represents control gain determined in advance, and P_I represents a value of the electric power that is actually outputted from the PWM converter 41.

$$P_T = P_T + \Delta P_T \cdots (4)$$

{0070}

In addition, the crane 1 according to the first embodiment can be transferred from the current lane R to another lane R. During the transfer of the crane 1 between the lanes R, the power supply apparatus 40 charges/discharges the battery 42 assuming that no electric power is supplied from the commercial power supply.

That is, even in the state where no electric power is supplied from the commercial power supply in order to transfer the crane 1 to another lane R, the crane 1 can be transferred to another lane R.

{0071}

More specifically, if the charge/discharge controlling apparatus 53 detects a state where no electric power is fed from the power feeding box 31, on the basis of a connection state signal of the power feeding connector 46, the input electric power target value P_{Itarget} is set to 0 (zero), the charge/discharge power command value P_T is calculated on the basis of Expression (2), and electric power charge/discharge control is performed for the electric power loads when no electric power is fed from the commercial power supply.

A given battery is selected in advance as the battery 42, the given battery having an electric power capacity that is large enough to cover the electric power consumed during the transfer of the crane 1 between the lanes R.

{0072}

As has been described above, the power supply apparatus 40 according to the first embodiment includes: the battery 42 for supplying the electric power to the electric power loads of the crane 1, the battery 42 being chargeable and dischargeable; and the PWM converter 41 that receives the supply of the predetermined electric power from the commercial power supply. The charge/discharge controlling apparatus 53 calculates the electric power difference between the electric power consumed by the electric power loads and the electric power supplied from the commercial power supply, and the charging/discharging apparatus 48 charges/discharges the electric power according to the calculated electric power difference to/from the battery 42.

Accordingly, in the power supply apparatus 40 according to the first embodiment, even if the predetermined electric power (input electric power target value $P_{I\text{target}}$) supplied from the commercial power supply is set to be low (for example, 45 kW), the electric power discharged from the storage battery assists the electric power supplied from the commercial power supply. As a result, the power supply apparatus 40 according to the first embodiment reduces the electric power supplied from the commercial power supply to the crane 1 to thereby enable low-voltage power transmission.

{0073}

Because the electric power supplied from the commercial

power supply to the electric power loads of the crane 1 is reduced, the size of the power feeding cable 33 leading to the crane 1 can be smaller, and the cable reel 47 can be downsized.

{0074}

[Second Embodiment]

Hereinafter, a second embodiment of the present invention is described.

{0075}

The configurations of a crane 1 and a power supply apparatus 40 according to the second embodiment are the same as the configurations of the crane 1 and the power supply apparatus 40 according to the first embodiment illustrated in Figs. 1 to 3, and hence description thereof is omitted.

{0076}

In the power supply apparatus 40 according to the second embodiment, the electric power supplied from the commercial power supply, that is, the input electric power target value P_{Itarget} is set to be variable within a range equal to or less than a predetermined electric power.

{0077}

For example, the power supply apparatus 40 changes the electric power (input electric power target value P_{Itarget}) supplied from the commercial power supply, on the basis of a history of a charge state of the battery 42.

{0078}

When the battery 42 reaches a full charge, the battery 42 cannot be charged any more. Accordingly, in the charge/discharge control of the battery 42 based on Expression (2), when the battery 42 reaches a full charge, the charge/discharge controlling apparatus 53 temporarily stops the charge of the battery 42 even in the case where the charge/discharge power command value P_T is negative.

{0079}

In such a case, the charge/discharge controlling apparatus 43 calculates in real time an incidence p of a state where the charge of the battery 42 is stopped due to its full charge even if the charge is necessary (the rate of charge stop time to total time for which the electric power is supplied from the commercial power supply), and calculates the input electric power target value $P_{I\text{target}}$.

{0080}

The input electric power target value $P_{I\text{target}}$ can be calculated on the basis of, for example, Expression (5).

$$P_{I\text{target}} = k \times (1 - p) \times P_{I\text{target}\cdot\text{Base}} \cdots (5)$$

where k represents a predetermined coefficient, and $P_{I\text{target}\cdot\text{Base}}$ represents a criterial input electric power target value (for example, 45 kW).

According to this expression, in the case where the incidence p is high, the input electric power target value

$P_{Itarget}$ changes to a small degree.

{0081}

The following is another example in which the power supply apparatus 40 changes the electric power supplied from the commercial power supply, on the basis of the history of the charge state of the battery 42. That is, the power supply apparatus 40 calculates in real time a slope α of a state of charge (SOC) of the battery 42, and calculates the input electric power target value $P_{Itarget}$ on the basis of Expression (6).

The slope α is obtained from, for example, the slope of a moving average of a temporal change in the state of charge, the moving average being calculated from a graph in which the horizontal axis represents time and the vertical axis represents the state of charge.

{0082}

Then, the input electric power target value $P_{Itarget}$ is calculated on the basis of, for example, Expression (6).

$$P_{Itarget} = k \times (1 - \alpha) \times P_{Itarget \cdot Base} \cdots (6)$$

According to this expression, in the case where the slope is positive, that is, the rate of the period during which the battery 42 is charged is larger, the input electric power target value $P_{Itarget}$ changes to a small degree.

{0083}

For still another example, the power supply apparatus 40

may change the electric power supplied from the commercial power supply, on the basis of a history of the electric power supplied to the electric power loads.

In this example, an average value (the average value from the current time point to before a predetermined time point) $P_{I\text{target}\cdot\text{average}}$ of the electric power consumed by the electric power loads is calculated, and as shown in Expression (7), the input electric power target value $P_{I\text{target}}$ is set to the average value $P_{I\text{target}\cdot\text{average}}$.

$$P_{I\text{target}} = P_{I\text{target}\cdot\text{average}} \cdots (7)$$

{0084}

In the variable control of the electric power supplied from the commercial power supply, for example, the charge/discharge controlling apparatus 53 calculates the input electric power target value $P_{I\text{target}}$ using any of Expressions (5) to (7) given above, and outputs the charge/discharge power command value P_T calculated in accordance with the calculation result, to the charging/discharging apparatus 48. Then, the charging/discharging apparatus 48 charges/discharges the electric power based on the charge/discharge power command value P_T to/from the battery 42.

{0085}

Alternatively, the power supply apparatus 40 may store in advance the input electric power target value $P_{I\text{target}}$ that is different in accordance with the incidence p or the slope α of

the state of charge, and may change the input electric power target value $P_{I\text{target}}$ in accordance with the incidence p or the slope α of the state of charge. The input electric power target value $P_{I\text{target}}$ may be 0 (zero) or negative. The case where the input electric power target value $P_{I\text{target}}$ is negative refers to the case where the crane 1 hoists down a suspension cargo. In this case, the motor 49 functions as a power generator to thereby generate electric power, and the generated electric power is regenerated to the commercial power supply.

{0086}

As has been described above, the power supply apparatus 40 according to the second embodiment changes the electric power supplied from the commercial power supply on the basis of the history of the charge state of the battery 42. Accordingly, in the case where the amount of charge in the battery 42 is large, the electric power supplied from the commercial power supply can be further reduced.

In addition, the power supply apparatus 40 changes the electric power supplied from the commercial power supply on the basis of the history of the electric power supplied to the electric power loads. Accordingly, in the case where the amount of electric power consumed by the electric power loads is small, the electric power supplied from the commercial power supply can be further reduced.

Because the power supply apparatus 40 according to the second embodiment reduces the electric power supplied from the commercial power supply, the electric power consumed by the resistor 51 can be cut down, leading to a reduction in the need to provide the resistor 51.

{0087}

[Third Embodiment]

Hereinafter, a third embodiment of the present invention is described.

{0088}

The configurations of a crane 1 and a power supply apparatus 40 according to the third embodiment are the same as the configurations of the crane 1 and the power supply apparatus 40 according to the first embodiment illustrated in Figs. 1 to 3, and hence description thereof is omitted.

{0089}

The electric power capacity of the battery 42 included in the power supply apparatus 40 needs to cover respective peak electric powers of the electric power loads. That is, it is effective to reduce the respective peak electric powers of the electric power loads in order to adopt the battery 42 having a smaller electric power capacity.

{0090}

In view of the above, the third embodiment reduces the peak of the electric power consumed by the electric power

loads at the time of a hoisting operation in which the crane 1 hoists a suspension cargo.

{0091}

Hereinafter, the hoisting operation of the crane 1 according to the third embodiment is specifically described.

{0092}

First, a limit value of the electric power supplied to the electric power loads (supplied electric power limit value P_{Llimit}) is set, and the hoisting operation is limited on the basis of the supplied electric power limit value P_{Llimit} .

{0093}

Here, the relation between the supplied electric power limit value P_{Llimit} to the electric power loads and the load consumed electric power P_L needs to satisfy Expression (8) given below.

$$P_L < P_{Llimit} \cdots (8)$$

{0094}

Then, the load consumed electric power P_L is subdivided as shown in Expression (9) and Expression (10) given below.

$$P_L = P_{MH} + P_{AUX} \cdots (9)$$

$$P_{MH} = (9.8 \times M \times V + a \times (M + J) \times V) \cdots (10)$$

In Expression (9), P_{MH} represents the electric power necessary for the hoisting operation (hoisting operation necessary electric power (kW)), and P_{AUX} represents a reference value of the electric power consumed by the auxiliary machine

50 (base electric power (kW)).

In Expression (10), M represents the suspension cargo mass (kg), V represents the hoisting speed (m/s), a represents the hoisting acceleration (m/s^2), and J represents a value (kg) obtained by converting the moment of inertia of a hoisting drum into mass.

{0095}

Then, the maximum hoisting speed V and the maximum acceleration a that can be outputted within a range of the supplied electric power limit value $P_{L\text{limit}}$ is calculated on the basis of Expression (10).

{0096}

The crane 1 according to the third embodiment changes the acceleration a in the hoisting operation in which a suspension cargo is hoisted, to thereby perform the hoisting operation so as to suppress the electric power consumed by the electric power loads, and the electric power capacity of the battery 42 is determined on the basis of the electric power suppressed through such a hoisting operation.

{0097}

With reference to Figs. 5, the hoisting operation according to the third embodiment is described.

Fig. 5(a) shows a temporal change in the speed of a conventional hoisting operation (hoisting speed), and Fig. 5(b) shows a temporal change in electric power consumed by the

conventional hoisting operation, the temporal change in electric power corresponding to Fig. 5(a).

{0098}

As shown in Fig. 5(b), an electric power peak appears when the hoisting speed is made constant after being increased.

Accordingly, in the third embodiment, in the case as shown in Fig. 5(b) where the consumed electric power becomes excessive in accordance with the acceleration of the hoisting operation of the crane 1, the acceleration of the hoisting operation is changed.

{0099}

Fig. 5(c) shows a temporal change in the speed of the hoisting operation (hoisting speed) according to the third embodiment, and Fig. 5(d) shows a temporal change in electric power consumed by the hoisting operation according to the third embodiment, the temporal change in electric power corresponding to Fig. 5(c).

In the hoisting operation according to the third embodiment, in order to make, as shown in Fig. 5(d), the consumed electric power equal to or less than the supplied electric power limit value P_{Llimit} set in advance, the acceleration of the hoisting operation before the hoisting speed is made constant is changed as shown in Fig. 5(c).

{0100}

The acceleration is changed so as to decrease, whereby the total time required for the hoisting operation is longer than that of the case where the acceleration is not changed. Accordingly, the hoisting speed to be made constant is increased compared with that of the case where the acceleration is not changed, whereby the total time required for the hoisting operation may be prevented from being longer.

{0101}

As has been described above, in the third embodiment, excessive consumed electric power is suppressed from occurring in the hoisting operation of the crane 1. Accordingly, the electric power capacity of the battery 42 can be determined on the basis of the electric power suppressed through the hoisting operation, and the battery 42 having a smaller electric power capacity can be adopted.

{0102}

[Fourth Embodiment]

Hereinafter, a fourth embodiment of the present invention is described.

Fig. 6 illustrates an electrical configuration of a crane 1 and an electrical configuration of a power supply apparatus 40 according to the fourth embodiment. In Fig. 6, the same components as those in Fig. 3 are denoted by the same reference signs as those in Fig. 3, and description thereof is omitted.

{0103}

A crane 1' according to the fourth embodiment is different from a conventional RTG including a power generator 61 (engine generator 66) that generates electric power through the drive of an engine 60 in that the existing power generator 61 is eliminated and that a power supply apparatus 40' replacing the existing power generator 61 is provided. In the conventional RTG, AC power outputted from the power generator 61 is supplied to the motors 49 and the auxiliary machines 50 via respective load driving inverters 62. In the crane 1' according to the fourth embodiment, the output of the power supply apparatus 40' replacing the existing power generator 61 is obtained as AC power, whereby the present embodiment is preferably adopted for modifying the conventional RTG.

{0104}

The power supply apparatus 40' according to the fourth embodiment includes: the battery 42; the PWM converter 41; and a DC/AC inverter 65 that converts DC power into AC power, for supplying electric power from the battery 42 and the PWM converter 41 to a power feeding path 63 leading to electric power loads of the crane 1'. The electric power loads of the crane 1' can be driven with the electric power supplied from the power supply apparatus 40'. In addition, in the power supply apparatus 40' according to the fourth embodiment, the load consumed electric power P_L is outputted from the DC/AC

inverter 65 to the charge/discharge controlling apparatus 53.
{0105}

That is, the power supply apparatus 40' according to the fourth embodiment is connected to a power feeding path leading to electric power loads of an existing crane 1' in which electric power is supplied to the electric power loads by the power generator 61, whereby the electric power loads of the existing crane 1' can be driven with the electric power supplied from the battery 42 and the commercial power supply.

Further, in the power supply apparatus 40' according to the fourth embodiment, even if the predetermined electric power supplied from the commercial power supply is set to be low (for example, 45 kW), the electric power discharged from the battery 42 assists the electric power supplied from the commercial power supply. Accordingly, the power supply apparatus 40' according to the fourth embodiment can reduce the electric power supplied from the commercial power supply to the crane.

{0106}

In the fourth embodiment, description is given above of the example in which the existing power generator 61 is eliminated from the crane 1', but the existing power generator 61 does not necessarily need to be eliminated from the crane 1'. The power supply apparatus 40' may be connected to the crane 1' with the existing power generator 61 being provided

in the crane 1'. In this case, the crane 1' may use the power generator 61 and the power supply apparatus 40' in combination to supply electric power to the electric power loads.

{0107}

Hereinabove, the present invention has been described by way of the embodiments, but the technical scope of the present invention is not limited to the features described above in the embodiments. The embodiments described above can be variously changed or improved within a range not departing from the gist of the present invention, and such changed or improved embodiments also fall within the technical scope of the present invention.

{Reference Signs List}

{0108}

- 1 crane
- 1' crane
- 40 power supply apparatus
- 40' power supply apparatus
- 41 PWM converter
- 42 battery
- 48 charging/discharging apparatus
- 49 motor
- 50 auxiliary machine
- 53 charge/discharge controlling apparatus
- 65 DC/AC inverter

{CLAIMS}

{Claim 1}

A power supply apparatus comprising:

a storage battery for supplying electric power to an electric power load of a crane, the storage battery being chargeable and dischargeable;

a power receiving unit for receiving supply of a predetermined electric power from a commercial power supply;

a calculating unit for calculating an electric power difference between the electric power consumed by the electric power load and the electric power supplied from the commercial power supply; and

a controlling unit for charging/discharging electric power according to the electric power difference calculated by the calculating unit, to/from the storage battery.

{Claim 2}

A power supply apparatus that supplies AC power to an electric power load of a crane including a power generator or a crane from which an existing power generator is eliminated, the power supply apparatus comprising:

a storage battery for supplying electric power to the electric power load, the storage battery being chargeable and dischargeable;

a power receiving unit for receiving supply of a

predetermined electric power from a commercial power supply;

a calculating unit for calculating an electric power difference between the electric power consumed by the electric power load and the electric power supplied from the commercial power supply;

a controlling unit for charging/discharging electric power according to the electric power difference calculated by the calculating unit, to/from the storage battery; and

a supplying unit for converting DC power from each of the storage battery and the power receiving unit into AC power and supplying the converted power to a power feeding path leading to the electric power load.

{Claim 3}

A power supply apparatus according to claim 1 or claim 2, wherein

the crane is transferrable from one lane to another lane, and

the controlling unit charges/discharges the storage battery during transfer of the crane between the lanes, assuming that no electric power is supplied from the commercial power supply.

{Claim 4}

A power supply apparatus according to any one of claim 1

to claim 3, wherein

the electric power supplied from the commercial power supply is set to be variable within a range equal to or less than the predetermined electric power.

{Claim 5}

A power supply apparatus according to claim 4, wherein

the controlling unit changes the electric power supplied from the commercial power supply, on a basis of a history of a charge state of the storage battery.

{Claim 6}

A power supply apparatus according to claim 4, wherein

the controlling unit changes the electric power supplied from the commercial power supply, on a basis of a history of the electric power supplied to the electric power load.

{Claim 7}

A power supply apparatus according to any one of claim 1 to claim 6, wherein

the crane changes acceleration in a hoisting operation in which a suspension cargo is hoisted, to thereby perform the hoisting operation so as to suppress the electric power consumed by the electric power load, and

an electric power capacity of the storage battery is

based on the electric power suppressed through the hoisting operation.

{Claim 8}

A crane comprising:

the power supply apparatus according to any one of claim 1 to claim 7; and

an electric power load that is driven with electric power supplied from the power supply apparatus.

{Claim 9}

A power supply method for supplying electric power to an electric power load of a crane,

the crane including:

a storage battery for supplying electric power to the electric power load, the storage battery being chargeable and dischargeable; and

a power receiving unit for receiving supply of a predetermined electric power from a commercial power supply,

the power supply method comprising:

a first stage of calculating an electric power difference between the electric power consumed by the electric power load and the electric power supplied from the commercial power supply; and

a second stage of charging/discharging electric

power according to the electric power difference calculated in the first stage, to/from the storage battery.

{Claim 10}

A power supply method for a power supply apparatus that supplies AC power to an electric power load of a crane including a power generator or a crane from which an existing power generator is eliminated,

the power supply apparatus including:

a storage battery for supplying electric power to the electric power load of the crane, the storage battery being chargeable and dischargeable;

a power receiving unit for receiving supply of a predetermined electric power from a commercial power supply; and

a supplying unit for converting DC power from each of the storage battery and the power receiving unit into AC power and supplying the converted power to a power feeding path leading to the electric power load,

the power supply method comprising:

a first stage of calculating an electric power difference between the electric power consumed by the electric power load and the electric power supplied from the commercial power supply; and

a second stage of charging/discharging electric

power according to the electric power difference calculated in the first stage, to/from the storage battery.