

DESCRIPTION

TRAVELING VEHICLE SYSTEM AND METHOD OF NON-CONTACT POWER
FEEDING TO TRAVELING VEHICLE

5 Field of the Invention

[0001]

The present invention relates to a traveling vehicle system. In particular, the present invention relates to non-contact power feeding to a traveling vehicle.

10 Background Art

[0002]

In a known technique, non-contact power feeding to a traveling vehicle such as a stacker crane is performed, and an energy storage unit such as a capacitor is provided to back up non-contact power feeding (Patent Publication 1: JP2008-081219A). Non-
15 contact power feeding eliminates dust emission due to contact, e.g., between a power feeder cable and a trolley, and the energy storage unit stores regenerative electrical energy from the traveling vehicle. Further, by leveling of the electrical power required for the non-contact power feeder cable, sizes of a power supply on the ground and a power receiving unit are reduced.

20 [0003]

In this regard, the inventor focused on the fact that, in the Patent Publication 1, electrical current is supplied from the power supply on the ground to the non-contact power feeder cable all the time, and that electrical energy is consumed due to the Joule heat generated by electrical current flowing through the non-contact power feeder cable
25 all the time. The inventor arrived at the present invention in an attempt to reduce the waste of electrical energy.

Summary of the Invention

[0004]

An object of the present invention is to reduce consumption of electrical energy due to the Joule heat generated by electrical current flowing through a non-contact power
5 feeder cable.

Another object of the present invention is to increase the amount of electrical energy that can be collected from an energy storage unit.

Still another object of the present invention is to make it possible to estimate the product life of the energy storage unit.

10 [0005]

The present invention relates to a system for supplying electrical energy to a traveling vehicle by non-contact power feeding. The system includes:

a power supply and a non-contact power feeder cable on a ground;

a traveling vehicle having a power receiving unit configured to receive electrical
15 energy from the non-contact power feeder cable, a load consuming electrical energy, and an energy storage unit configured to store electrical energy from the power receiving unit and regenerative electrical energy from the load, and supply electrical energy to the load; and

control means for keeping track of an amount of electrical energy stored in the
20 energy storage unit and an amount of electrical energy required for the load, and stopping supply of electrical energy to the non-contact power feeder cable when the electrical energy required for the load can be supplied by the electrical energy stored in the energy storage unit.

[0006]

25 Further, the present invention relates to a method of supplying electrical energy to a traveling vehicle by non-contact power feeding. The method includes the steps of:
providing a power supply and a non-contact power feeder cable on a ground;

providing a traveling vehicle with a power receiving unit configured to receive electrical energy from the non-contact power feeder cable, a load consuming electrical energy, and an energy storage unit configured to store electrical energy from the power receiving unit and regenerative electrical energy from the load, and supply electrical
5 energy to the load; and

keeping track of an amount of electrical energy stored in the energy storage unit and an amount of electrical energy required for the load by control means, and stopping supply of electrical energy to the non-contact power feeder cable by the control means when the electrical energy required for the load can be supplied by the electrical energy
10 stored in the energy storage unit.

In the specification, the description regarding the traveling vehicle system is directly applicable to the non-contact power feeding method, and conversely, the description regarding the non-contact power feeding method is directly applicable to the description regarding the traveling vehicle system.

15 [0007]

In the present invention, supply of electrical energy to the non-contact power feeder cable is stopped when the electrical energy required for the load is available without non-contact power feeding. Therefore, consumption of electrical energy corresponding to the Joule heat resulting from reactive current can be eliminated.

20 Determination as to whether the required electrical energy is available or not can be made, e.g., by determining whether the required electrical energy is available or not from the start to end of the next operation of the traveling vehicle. Non-contact power feeding should be performed in the segment where the required electrical energy for the next operation is not available, and non-contact power feeding should be stopped in the
25 segment where the required electrical energy for the next operation is available.

[0008]

More preferably, the energy storage unit is a capacitor. The traveling vehicle

system further includes a voltage sensor configured to monitor voltage of the energy storage unit, electrical current sensor configured to monitor electrical current of electrical energy charged in, and discharged from the energy storage unit, and product life estimation means for determining capacitance of the energy storage unit based on the voltage of the energy storage unit and electrical current of electrical energy charged in, and discharged from the energy storage, for estimating product life of the energy storage unit.

In particular, preferably, the product life estimation means is configured to determine internal resistance of the energy storage unit based on a change in the voltage of the energy storage unit, for estimating the product life based on the capacitance and the internal resistance of the energy storage unit.

In this manner, when the end of the product life approaches, a capacitor for replacement is stocked. When the end of the product life comes, the capacitor can be replaced immediately. Therefore, it is not necessary to stop operation of the traveling vehicle for waiting for the arrival of a new capacitor for replacement.

[0009]

Preferably, the power receiving unit and the load are connected in parallel to the traveling vehicle. Further, the energy storage unit is connected to the traveling vehicle through a circuit for controlling charging of electrical energy into, and discharging of electrical energy from the energy storage unit. For example, in an example of the circuit for controlling charging of electrical energy into, and discharging of electrical energy from the energy storage unit, a first transistor configured to control charging of electrical energy is connected to a plus terminal of the energy storage unit through a coil, and a second transistor configured to control discharging of electrical energy is connected between the coil and the first transistor, and the emitter of the second transistor is connected to a minus terminal of the energy storage unit. The input and output of the charging and discharging control circuit are the cathode of the first transistor and the

minus terminal of the energy storage unit. By implementing PWM control of the first transistor, the electrical current (electrical energy) charged in the energy storage unit can be controlled arbitrarily. Further, by implementing PWM control of the second transistor, the electrical current (electrical energy) discharged from the energy storage unit can be controlled arbitrarily. By using the charging and discharging control circuit operated in this manner, the available voltage range of the energy storage unit is widened, and a larger electrical energy can be collected from a smaller energy storage unit.

[0010]

Further, the traveling vehicle system of the present invention is a system for supplying electrical energy to a traveling vehicle by non-contact power feeding. The system includes:

a power supply and a non-contact power feeder cable on a ground;

a traveling vehicle having a power receiving unit configured to receive electrical energy from the non-contact power feeder cable, a load consuming electrical energy, and an energy storage unit configured to store electrical energy from the power receiving unit and regenerative electrical energy from the load, and supply electrical energy to the load; and

control means for keeping track of an amount of electrical energy stored in the energy storage unit, and stopping supply of electrical energy to the non-contact power feeder cable when electrical energy stored in the energy storage unit has a predetermined value or more.

[0011]

By adopting the structure, supply of electrical energy to the non-contact power feeder cable is stopped when the electrical energy required for the load is available without non-contact power feeding. Therefore, consumption of electrical energy corresponding to the Joule heat resulting from reactive electrical current can be eliminated.

Brief Description of the Drawings

[0012]

[FIG. 1]

5 FIG. 1 is a plan view showing main components of a traveling vehicle system according to an embodiment.

[FIG. 2]

 FIG. 2 is a block diagram showing main components of traveling vehicle system according to the embodiment.

10 [FIG. 3]

 FIG. 3 is a block diagram showing main components of a traveling vehicle according to the embodiment.

[FIG. 4]

 FIG. 4 is a flow chart showing an ON/OFF algorithm of non-contact power
15 feeding according to the embodiment.

[FIG. 5]

 FIG. 5 includes characteristic graphs showing power management of the traveling
vehicle in the embodiment where a graph 1) shows a pattern of required electrical energy,
a graph 2) shows an amount of stored electrical energy, and a graph 3) shows transition
20 of discharged electrical current.

[FIG. 6]

 FIG. 6 is a graph showing a method of measuring capacitance C and internal
resistance R of a capacitor in the embodiment.

[FIG. 7]

25 FIG. 7 is a graph showing a method of measuring capacitance C and internal
resistance R of a capacitor in a modified embodiment.

EMBODIMENT

[0013]

Hereinafter, an embodiment for carrying out the present invention in the most preferred form will be described. The scope of the invention shall be determined according to understanding of a person skilled in the art based on the description of the claims in consideration of the description of the specification and techniques known in this technical field.

[0014]

FIGS. 1 to 7 show a traveling vehicle system 2 according to the embodiment and its modification. A reference numeral 4 denotes a traveling vehicle. In the embodiment, the traveling vehicle 4 is a stacker crane in an automated warehouse. Alternatively, for example, an overhead traveling vehicle, or a rail vehicle that travels along a rail may be used as the traveling vehicle 4. A reference numeral 6 denotes a carriage of the traveling vehicle 4. An elevation frame 8 is elevated and lowered along the mast 10, and the article is transferred to a rack 25 or the like by a slide fork 12 on the elevation frame 8. A reference numeral 14 denotes a travel motor driven for travel of the carriage 6. A reference numeral 15 denotes an elevation motor for elevation of the elevation frame 8. A capacitor 16 stores electricity (electrical energy) supplied from a non-contact power feeder cable 26. Instead of the capacitor 16, a secondary battery such as a lithium ion battery may be used for storing electrical energy.

[0015]

A reference numeral 18 denotes a power panel for supplying electrical energy to loads such as the travel motor 14, the elevation motor 15, and the slide fork 12. A reference numeral 20 denotes a chopper unit. A power receiving unit 22 receives electrical energy from the non-contact power feeding cable 26, and high frequency electrical current is applied to the non-contact power feeder cable 26 from the a power supply 28 on the ground. The power receiving unit 22, the power panel 18, and the

capacitor 16 are connected by the chopper unit 20. The power panel 18 supplies electrical energy to the loads, and discharges regenerative electrical energy from the loads.

[0016]

5 FIG. 2 is a block diagram showing a power supply system of the traveling vehicle

4. The power receiving unit 22 includes a core unit 30 and a rectifier unit 31. The core unit 30 includes a core made of magnetizable material, and a pickup coil. The rectifier unit 31 rectifies the high frequency electrical current from the core unit 30, and then, supplies the rectified high frequency electrical current to the chopper unit 20. A

10 controller 32 of the power panel 18 outputs a prediction value regarding electrical energy required for the loads in the future. For example, the controller 32 outputs electrical energy required for the next operation of the traveling vehicle and regenerative electrical energy. The direct current electricity is supplied from the power panel 18 to the other loads 34 such as the travel motor 14, the elevation motor 15, and the slide fork, and
15 regenerative electrical energy is supplied to the chopper unit 20. A reference numeral 19 denotes a breaker provided between the chopper unit 20 and the power panel 18.

[0017]

 The chopper unit 20 receives a report from the capacitor 16 regarding the amount of stored electrical energy such as the output voltage of the capacitor 16, and determines
20 whether the required electrical energy having the prediction value can be supplied only by the electrical energy from the capacitor 16. Based on the determination result, a request to turn on or turn off the power supply 28 on the ground is made. It should be noted that the prediction value regarding the amount of energy required in the future and the amount of electrical energy stored in the capacitor may be obtained by the controller
25 32 or the power supply 28 on the ground instead of the chopper unit 20, to determine whether the power supply should be turned on or turned off.

[0018]

FIG. 3 shows structure of the chopper unit 20. reference numerals D1, D2 denote diodes, and reference numerals Tr1, Tr2 denote large power transistors. The reference numeral Tr1 denotes a first transistor, and the reference numeral Tr2 denotes a second transistor. A reference numeral C1 denotes a smoothing capacitor, and a reference L1 denotes a coil. A reference numeral S1 denotes a voltage sensor for monitoring the output voltage of the capacitor 16, and a reference numeral S2 denotes a current sensor for monitoring electrical current flowing through capacitor 16. Additionally, in the power receiving unit 22 and the power panel 18, the electrical current flowing through each component and the voltage applied to each component are monitored. A control means 40 controls the transistors Tr1, Tr2, and determines whether non-contact power feeding is required or not based on prediction regarding the loads and the amount of electrical energy stored in the capacitor 16. The information indicating whether non-contact power feeding is required or not is communicated from a communication interface 41 to the power supply 28 on the ground. Further, the control means 40 determines the capacitance and internal resistance of the capacitor 16, and stores these items of data. Based on these values and the voltage of the capacitor 16, the amount of stored electrical energy is determined. Further, based on the capacitance and internal resistance, the remaining product life of the capacitor 16 is estimated. Further, when the end of the product life of the capacitor 16 approaches, information to this effect is notified to the power supply 28 on the ground or the like. The internal resistance may not be measured.

[0019]

In the case of charging the capacitor 16 using the electrical energy from the power receiving unit 22, or the regenerative electrical energy from the power panel 18, PWM control of the transistor Tr1 is implemented, and the transistor Tr2 is turned off. In the case of discharging electrical energy from the capacitor 16, the transistor Tr1 is turned off, and PWM control of the transistor Tr2 is implemented. When the transistor Tr2 is

turned on, electrical current flowing through the coil L1 is increased, and electrical energy is stored in the coil L1. In this state, by turning off the transistor Tr2, the coil L1 is placed in series with the energy storage unit, and the electrical energy stored in the coil L1 is outputted to the outside through the diode D1.

5 [0020]

FIG. 4 shows an algorithm of determining whether non-contact power feeding is required or not. The amount of electrical energy (electricity) stored in the capacitor is determined, and then, prediction values regarding the electrical energy required for the next operation of the traveling vehicle 4 and the regenerative electrical energy or the like are obtained. Based on the stored electrical energy and the energy prediction values, it is determined whether non-contact power feeding is required or not, and the resulting information is notified from the communication interface to the ground. For example, before operating the traveling vehicle, based on the data of the traveling vehicle such as the weight, acceleration, velocity, deceleration, movement distance, mechanical losses including frictional resistance, efficiency of the decelerator or the like, power losses, e.g., efficiency of components such as the servo motor, servo amplifier or the like, the amounts of electrical energies related to operation of the traveling vehicle are calculated. For example, the amounts of electrical energies are the amount of electrical energy required at the time of acceleration, the instantaneous maximum required electrical energy, the amount of regenerative electrical energy, the instantaneous maximum regenerative electrical energy, power consumption at the time of constant velocity operation. These values are calculated in respect of all of the axes of movement including the travel axis, the elevation axis, the rotation axis, and the transfer axis. At the time of acceleration, it is determined whether the amount of electrical energy discharged from the energy storage unit is sufficient or not. If the amount of electrical energy is not sufficient, non-contact power feeding is requested. Further, it is determined whether all of the regenerative electrical energy at the time of deceleration can be charged in the

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energy storage unit or not. If all of the regenerative electrical energy cannot be charged in the energy storage unit, the proportion of electrical energy relying on non-contact power feeding is reduced and the amount of electrical energy discharged from the capacitor is increased at the time of acceleration. If the traveling vehicle is operated only to lower the elevation frame without any traveling, energy consumption is small, and only the regenerative electrical energy becomes large. Such operation occurs only in the mode of transportation between the racks. Therefore, in such a mode, for example, in consideration of the energy consumption and the regenerative electrical energy until operation after the next operation, it is determined whether non-contact power feeding is required or not for making it possible to charge the regenerative electrical energy.

[0021]

A graph 1) of FIG. 5 shows transition of the required electrical energy and the regenerative electrical energy in one operation of the traveling vehicle. A graph 2) shows transition of the amount of electrical energy stored in the capacitor. A graph 3) shows transition of discharged electrical current (electrical energy). At the time of acceleration, large electrical energy is required. At the time of steady operation in the next period, energy consumption is small. Then, at the time of deceleration in the next period, regenerative electrical energy is generated. Also at the time of rotation of the turntable, operation of the slide fork or the like after travel of the traveling vehicle is stopped, energy consumption occurs. During the period, the amount of electrical energy stored in the capacitor is maintained within a predetermined range. The electrical power is leveled using non-contact power feeding for preventing the electrical current from the capacitor from exceeding the maximum discharge current. Further, deceleration or the like is limited to prevent electrical current supplied to the capacitor from exceeding the maximum charge current. In a segment where non-contact power feeding is performed, supply of electrical energy to the power feeder cable is stopped.

[0022]

FIGS. 6 and 7 show monitoring of the product life of the capacitor 16. In FIG. 6 (in the embodiment), the capacitor 16 is charged, e.g., by the steady current i when the traveling vehicle 4 is stopped or the like, and the change in the voltage V in the charging process is measured. In this manner, the capacitance C of the capacitor 16 can be measured. When charging is finished, the absence of the voltage drop for $R \times i$ based on the internal resistance corresponds to the voltage drop ΔV . Therefore, the internal resistance can be measured by measuring the voltage drop ΔV . Further, the capacitance C can be measured by comparing an accumulated value of the electrical current i with the change in the voltage, without relying on the steady current. Moreover, the internal resistance can be measured from the raise in the voltage ΔV when charging is started.

[0023]

FIG. 7 shows a modified example of monitoring the product life of the capacitor 16. When electrical energy is discharged from the capacitor 16, an accumulated value of the discharge current i is compared with the change in the voltage to measure the capacitance. Further, based on the change ΔV in the voltage at the time of the end or start of discharging of electrical energy and the electrical current immediately before the end of discharging of electrical energy or electrical current immediately after the start of discharging of electrical energy, the internal resistance R is measured.

[0024]

Modification of the embodiment will be shown. In the embodiment, when the load is high, both of the electrical energy from the capacitor 16 and the electrical energy from the power receiving unit are used. Alternatively, the capacitor 16 may be used as a main power supply to drive the load only using the electrical energy from the capacitor 16. In this case, non-contact power feeding may be performed only for charging of the capacitor 16.

[0025]

In the embodiment, when electrical energy for the loads can be supplied only by

the capacitor 16, and charging of the capacitor 16 is not required, the power supply on the ground is turned off. In this manner, the reactive power consumption for the Joule heat due to the electrical current flowing through the non-contact power feeder cable is reduced. Further, electrical energy that can be collected from the capacitor 16 is increased. Further, the product life of the capacitor 16 can be estimated. By stocking an additional capacitor 16 for replacement beforehand, the period in which the traveling vehicle 4 is not operated can be shortened.

Description of the numerals

10 [0026]

2: traveling vehicle system

4: traveling vehicle

6: carriage

8: elevation frame

15 10: mast

12: slide fork

14: travel motor

15: elevation motor

16: capacitor

20 18: power panel

19: breaker

20: chopper unit

22: power receiving unit

24: travel rail

25 25: rack

26: non-contact power feeder cable

28: power supply on the ground

30: core unit

31: rectifier unit

32: controller

34: other load

5 C1: capacitor

D1, D2: diode

Tr1, Tr2: transistor

L1: coil

S1: voltage sensor

10 S2: current sensor

40: control means

41: communication interface

WHAT IS CLAIMED IS:

1. A system for supplying electrical energy to a traveling vehicle by non-contact power feeding, the system comprising:

5 a power supply;

a non-contact power feeder cable on a ground;

a traveling vehicle having a power receiving unit configured to receive electrical energy from the non-contact power feeder cable, a load consuming electrical energy, and an energy storage unit configured to store electrical energy from the power receiving unit and regenerative electrical energy from the load, and supply electrical energy to the load; and

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control means for monitoring an amount of electrical energy stored in the energy storage unit estimating an amount of necessary electrical energy for the load and an amount of regenerative electrical energy from the load during a next operation of the traveling vehicle, determining whether the amount of the electrical energy stored in the energy storage unit is enough for an amount of necessary electrical energy for the load for acceleration during the next operation, requiring the non-contact power feeding from the power supply when the amount of electrical energy stored in the energy storage is not enough, and not requiring the non-contact power feeding when the amount of electrical energy stored in the energy storage is enough.

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2. The traveling vehicle system according to claim 1, the energy storage unit being a capacitor, the traveling vehicle system further comprising:

a voltage sensor configured to monitor voltage of the energy storage unit;

25 electrical current sensor configured to monitor electrical current of electrical energy charged in, and discharged from the energy storage unit; and

product life estimation means for determining capacitance of the energy storage

unit based on the voltage of the energy storage unit and electrical current of electrical energy charged in, and discharged from the energy storage, for estimating product life of the energy storage unit.

5 3. The traveling vehicle system according to claim 2, the product life estimation means being configured to determine internal resistance of the energy storage unit based on a change in the voltage of the energy storage unit, for estimating the product life based on the capacitance and the internal resistance of the energy storage unit.

10 4. The traveling vehicle system according to any one of claims 1 to 3, the power receiving unit and the load being connected in parallel to the traveling vehicle, a first transistor, a diode, and a second transistor being provided between the power receiving unit and the load arranged in parallel, the first transistor being configured to control charging of electrical energy from the power receiving unit to the energy storage unit, the
15 diode being provided in parallel with the first transistor for discharging electrical energy from the energy storage unit, the second transistor connecting a plus terminal and a minus terminal of the energy storage unit, a coil being provided between the first and second transistors and the energy storage unit.

20 5. A method of supplying electrical energy to a traveling vehicle by non-contact power feeding, the method comprising the steps of:

 providing a power supply and a non-contact power feeder cable on a ground;
 providing a traveling vehicle with a power receiving unit configured to receive electrical energy from the non-contact power feeder cable, a load consuming electrical
25 energy, and an energy storage unit configured to store electrical energy from the power receiving unit and regenerative electrical energy from the load, and supply electrical energy to the load; and

monitoring an amount of electrical energy stored in the energy storage unit
estimating an amount of necessary electrical energy for the load and an amount of
regenerative electrical energy from the load during a next operation of the traveling
vehicle, determining whether the amount of the electrical energy stored in the energy
5 storage unit is enough for an amount of necessary electrical energy for the load for
acceleration during the next operation, requiring the non-contact power feeding from the
power supply when the amount of electrical energy stored in the energy storage is not
enough, and not requiring the non-contact power feeding when the amount of electrical
energy stored in the energy storage is enough.