

US Patent & Trademark Office

Patent Public Search | Text View

United States Patent Application Publication

20250262956

Kind Code

A1

Publication Date

August 21, 2025

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VEHICLE, ELECTRIC POWER SUPPLY APPARATUS, AND ELECTRIC POWER SUPPLY METHOD

Abstract

A vehicle is provided with a battery configured to store electric power; a power receiving apparatus provided with a power receiving coil for receiving electric power from a power transmitting coil provided at a road; a motor configured to output drive power of the vehicle; an electric power supply circuit configured to supply electric power from at least one of the battery and the power receiving apparatus to the motor; and a control device configured to control the supply of electric power to the motor. The control device is further configured to select a source of supply of electric power to the motor from the battery and the power receiving apparatus in accordance with whether the vehicle is running in a power supply area at which the power transmitting coil is provided.

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Appl. No.:	18/868495
Filed (or PCT Filed):	April 21, 2023
PCT No.:	PCT/JP2023/015973

Foreign Application Priority Data

JP 2022-097601 Jun. 16, 2022

Publication Classification

Int. Cl.: B60L53/12 (20190101); B60L5/00 (20060101); B60L50/60 (20190101)

U.S. Cl.:

CPC B60L53/12 (20190201); B60L5/005 (20130101); B60L50/60 (20190201);

Background/Summary

CROSS-REFERENCE TO RELATED APPLICATIONS [0001] This application is a U.S. National Phase application of PCT/JP2023/015973 filed Apr. 21, 2023, which claims priority to Japanese Patent Application No. 2022-097601 filed Jun. 16, 2022, the entire contents of which are herein incorporated by reference.

FIELD

[0002] The present disclosure relates to a vehicle, electric power supply apparatus, and electric power supply method.

BACKGROUND

[0003] Known in the past has been the art of using a transmission system such as a magnetic resonance system to transmit electric power by noncontact. For example, Japanese Unexamined Patent Publication No. 2021-129432 describes to transmit electric power from a power transmitting coil provided at a road surface to a power receiving coil provided at a vehicle and to use that electric power to charge a battery of the vehicle while the vehicle is running.

SUMMARY

Technical Problem

[0004] In this regard, when the allowable charged electric power of the battery is small, it is not possible to supply the electric power transmitted to the vehicle to the battery. Therefore, it may be considered to directly supply the electric power received by the power receiving apparatus of the vehicle to the drive motor of the vehicle without going through the battery. However, if there are two options of the battery and the power receiving apparatus as the source of supply of electric power to the motor, it is necessary to suitably select which to use in accordance with the running environment of the vehicle etc.

[0005] Therefore, in consideration of the above problem, an object of the present disclosure is to suitably select the source of supply of electric power to the motor in a vehicle configured so as to be supplied with power by noncontact from a power transmitting coil provided at a road.

Solution to Problem

[0006] The gist of the present disclosure is as follows:

[0007] (1) A vehicle, the vehicle comprising: a battery configured to store electric power; a power receiving apparatus provided with a power receiving coil for receiving electric power from a power transmitting coil provided at a road; a motor configured to output drive power of the vehicle; an electric power supply circuit configured to supply electric power from at least one of the battery and the power receiving apparatus to the motor; and a control device configured to control the supply of electric power to the motor, wherein the control device is further configured to select a

source of supply of electric power to the motor from the battery and the power receiving apparatus in accordance with whether the vehicle is running in a power supply area at which the power transmitting coil is provided.

[0008] (2) The vehicle according to the above (1), wherein the control device is further configured to select only the power receiving apparatus as the source of supply of electric power when the vehicle is running in the power supply area.

[0009] (3) The vehicle according to the above (1), wherein the control device is further configured to select only the power receiving apparatus as the source of supply of electric power when the vehicle is running in the power supply area and a consumed electric power of the motor is less than or equal to a predetermined value and to select the battery and the power receiving apparatus as the source of supply of electric power when the consumed electric power is greater than the predetermined value.

[0010] (4) The vehicle according to the above (2) or (3), wherein the control device is further configured to select only the battery as the source of supply of electric power even when the vehicle is running in the power supply area, if trouble arises in supply of power to the vehicle.

[0011] (5) The vehicle according to any one of the above (1) to (3), wherein the control device is further configured to supply electric power from the power receiving apparatus to the motor and the battery when selecting only the power receiving apparatus as the source of supply of electric power and the amount of power supplied to the vehicle is greater than the electric power consumed by the motor.

[0012] (6) The method of supply of electric power to a motor for outputting drive power of a vehicle, in which electric power supply method, the vehicle comprising: a battery for storing electric power; a power receiving apparatus having a power receiving coil for receiving electric power from a power transmitting coil provided at a road; and an electric power supply circuit configured so as to supply electric power from at least one of the battery and the power receiving apparatus to the motor, the electric power supply method comprising selecting a source of supply of electric power to the motor from the battery and the power receiving apparatus in accordance with whether the vehicle is running in a power supply area at which the power transmitting coil is provided.

[0013] (7) An electric power supply apparatus mounted in a vehicle, wherein, the vehicle comprises: a battery for storing electric power; a power receiving apparatus having a power receiving coil for receiving electric power from a power transmitting coil provided at a road; a motor for outputting drive power of the vehicle; and an electric power supply circuit configured so as to supply electric power from at least one of the battery and the power receiving apparatus to the motor, and the electric power supply apparatus is configured to select a source of supply of electric power to the motor from the battery and the power receiving apparatus in accordance with whether the vehicle is running in a power supply area at which the power transmitting coil is provided.

[0014] (8) The electric power supply apparatus according to the above (7), further configured to select only the power receiving apparatus as the source of supply of electric power when the vehicle is running in the power supply area.

[0015] (9) The electric power supply apparatus according to the above (7), further configured to select only the power receiving apparatus as the source of supply of electric power when the vehicle is running in the power supply area and a consumed electric power of the motor is less than or equal to a predetermined value and to select the battery and the power receiving apparatus as the source of supply of electric power when the consumed electric power is greater than the predetermined value.

[0016] (10) The electric power supply apparatus according to the above (8) or (9), wherein the vehicle selects only the battery as the source of supply of electric power even when the vehicle is running in the power supply area, if trouble arises in supply of power to the vehicle.

[0017] (11) The electric power supply apparatus according to any one of the above (7) to (9),

further configured to supply electric power from the power receiving apparatus to the motor and the battery when selecting only the power receiving apparatus as the source of supply of electric power and the amount of power supplied to the vehicle is greater than the electric power consumed by the motor.

Effect

[0018] According to the present disclosure, it is possible to suitably select a source of supply of electric power to a motor in a vehicle configured so as to be supplied with power by noncontact from a power transmitting coil provided at a road.

Description

DESCRIPTION OF DRAWINGS

[0019] FIG. 1 is a view schematically showing the configuration of a noncontact power supply system.

[0020] FIG. 2 is a circuit diagram showing a path of supply of electric power in a vehicle.

[0021] FIG. 3 is a view schematically showing the configuration of an ECU of a vehicle and equipment connected to the ECU.

[0022] FIG. 4 is a view showing one example of a power supply area at which power transmitting coils of power supply apparatuses are installed.

[0023] FIG. 5 is a view showing a plurality of states of switching elements set by the ECU in a first embodiment.

[0024] FIG. 6 is a flow chart showing a control routine of the processing for supply of electric power in the first embodiment.

[0025] FIG. 7 is a view showing a plurality of states of switching elements set by the ECU in a second embodiment.

[0026] FIG. 8 is a flow chart showing a control routine of the processing for supply of electric power in the second embodiment.

[0027] FIG. 9 is a view showing a plurality of states of switching elements set by the ECU in a third embodiment.

[0028] FIG. 10 is a flow chart showing a control routine of the processing for supply of electric power in the third embodiment.

DESCRIPTION OF EMBODIMENTS

[0029] Below, referring to the drawings, embodiments of the present disclosure will be explained in detail. Note that, in the following explanation, similar component elements will be assigned the same reference notations.

[0030] First, the configuration for using a power supply apparatus to supply electric power by noncontact will be explained. FIG. 1 is a view schematically showing the configuration of a noncontact power supply system **100**. The noncontact power supply system **100** is comprised of a power supply apparatus **30** and a vehicle **1** and supplies power by noncontact between the power supply apparatus **30** and the vehicle **1**. In particular, in the present embodiment, the noncontact power supply system **100** supplies power by noncontact from the power supply apparatus **30** to the vehicle **1** by magnetic resonant coupling (magnetic resonance) when the vehicle **1** is running. That is, the noncontact power supply system **100** transmits electric power from the power supply apparatus **30** to the vehicle **1** using a magnetic field as a medium. Note that, noncontact power supply is also referred to as noncontact electric power transmission, wireless electric power transmission, and wireless power supply.

[0031] The power supply apparatus **30** is configured so as to supply electric power by noncontact to the vehicle **1**. Specifically, as shown in FIG. 1, the power supply apparatus **30** is provided with a power supply **31**, controller **32**, communication device **33**, and power transmission device **40**. In

the present embodiment, the power supply apparatus **30** is provided at a road (lane) on which the vehicle **1** is running and, for example, is buried in the ground (below road surface). Note that, at least part of the power supply apparatus **30** (for example, the power supply **31**, controller **32**, and communication device **33**) may be installed on the road surface.

[0032] The power supply **31** is a source of electric power of the power transmission device **40** and supplies electric power to the power transmission device **40**. The power supply **31** is, for example, a commercial AC power supply for supplying single-phase AC electric power. Note that, the power supply **31** may be an AC power supply for supplying three-phase AC electric power etc.

[0033] The power transmission device **40** is configured so as to generate an AC magnetic field for transmitting electric power to the vehicle **1**. In the present embodiment, the power transmission device **40** is provided with a power transmitting side rectification circuit **41**, inverter **42**, and power transmitting side resonance circuit **43**. In the power transmission device **40**, suitable AC electric power (high frequency electric power) is supplied through the power transmitting side rectification circuit **41** and inverter **42** to the power transmitting side resonance circuit **43**.

[0034] The power transmitting side rectification circuit **41** is electrically connected to the power supply **31** and inverter **42**. The power transmitting side rectification circuit **41** rectifies the AC electric power supplied from the power supply **31** to convert it to DC electric power and supplies the DC electric power to the inverter **42**. The power transmitting side rectification circuit **41** is for example an AC/DC converter.

[0035] The inverter **42** is electrically connected to the power transmitting side rectification circuit **41** and power transmitting side resonance circuit **43**. The inverter **42** converts the DC electric power supplied from the power transmitting side rectification circuit **41** to AC electric power of a higher frequency than the AC electric power of the power supply **31** (high frequency electric power) and supplies the high frequency electric power to the power transmitting side resonance circuit **43**.

[0036] The power transmitting side resonance circuit **43** has a resonator comprised of a power transmitting coil **44** and power transmitting side capacitor **45**. The various parameters of the power transmitting coil **44** and power transmitting side capacitor **45** (outside diameter and inside diameter of power transmitting coil **44**, number of turns of power transmitting coil **44**, electrostatic capacitance of power transmitting side capacitor **45**, etc.) are set so that the resonance frequency of the power transmitting side resonance circuit **43** becomes a predetermined setting. In some embodiments, the predetermined setting is, for example, 10 kHz to 100 GHz, or it is 85 kHz set by the SAE TIR J2954 standard as the frequency band for noncontact power supply of a vehicle.

[0037] The power transmitting side resonance circuit **43** is arranged at the center of the lane in which the vehicle **1** is running so that the center of the power transmitting coil **44** is positioned at the center of the lane. If the high frequency electric power supplied from the inverter **42** is applied to the power transmitting side resonance circuit **43**, the power transmitting side resonance circuit **43** makes an AC magnetic field be generated for transmitting electric power to the vehicle **1**. Note that, the power supply **31** may also be a DC power supply such as a fuel cell or solar cell. In this case, the power transmitting side rectification circuit **41** may be omitted. Further, between the inverter **42** and the power transmitting side resonance circuit **43**, a filter circuit suppressing high frequency noise generated from the inverter **42** may also be provided.

[0038] The controller **32** is, for example, a general use computer and performs various control of the power supply apparatus **30**. For example, the controller **32** is electrically connected to the inverter **42** of the power transmission device **40** and controls the inverter **42** so as to control power transmission by the power transmission device **40**.

[0039] The communication device **33** is a device for enabling communication between the power supply apparatus **30** and the outside of the power supply apparatus **30**. For example, the communication device **33** includes a short range wireless communication module (for example, DSRC (dedicated short range communication) antenna, Bluetooth™ module, etc.) for performing

short range wireless communication and long range wireless communication module for performing long range wireless communication. The communication device **33** is electrically connected to the controller **32**. The controller **32** uses the communication device **33** to communicate with the vehicle **1**.

[0040] On the other hand, the vehicle **1** is provided with a power receiving apparatus **2** and is configured so as to be supplied with power by noncontact by the power supply apparatus **30**. In the present embodiment, the power receiving apparatus **2** has a power receiving side resonance circuit **21**, power receiving side rectification circuit **24**, and DC/DC converter **25**.

[0041] The power receiving side resonance circuit **21** is arranged at the floor part of the vehicle **1** so that the distance from the road surface becomes shorter. In the present embodiment, the power receiving side resonance circuit **21** is arranged at the center of the vehicle **1** in the vehicle width direction and is arranged between the front wheels and rear wheels in the front-rear direction of the vehicle **1**.

[0042] The power receiving side resonance circuit **21** is configured in the same way as the power transmitting side resonance circuit **43** and has a resonator comprised of a power receiving coil **22** and power receiving side capacitor **23**. The various parameters of the power receiving coil **22** and power receiving side capacitor **23** (outside diameter and inside diameter of power receiving coil **22**, number of turns of power receiving coil **22**, electrostatic capacitance of power receiving side capacitor **23**, etc.) are set so that the resonance frequency of the power receiving side resonance circuit **21** matches the power transmitting side resonance circuit **43**. Note that, if the amount of deviation of the resonance frequency of the power receiving side resonance circuit **21** and the resonance frequency of the power transmitting side resonance circuit **43** is small, for example, if the resonance frequency of the power receiving side resonance circuit **21** is within a range of $\pm 20\%$ of the resonance frequency of the power transmitting side resonance circuit **43**, there is no need for the resonance frequency of the power receiving side resonance circuit **21** to necessarily match the resonance frequency of the power transmitting side resonance circuit **43**.

[0043] As shown in FIG. **1**, when the power receiving coil **22** of the power receiving side resonance circuit **21** faces the power transmitting coil **44** of the power transmitting side resonance circuit **43**, if an AC magnetic field is emitted from the power transmitting coil **44**, the vibration of the AC magnetic field is transmitted to the power receiving side resonance circuit **21** resonating at the same resonance frequency as the power transmitting side resonance circuit **43**. As a result, due to electromagnetic induction, an induction current flows to the power receiving coil **22** of the power receiving side resonance circuit **21**. Due to the induction current, electric power is generated. That is, the power receiving coil **22** receives electric power from the power transmitting coil **44** provided at the road.

[0044] The power receiving side rectification circuit **24** is electrically connected to the power receiving side resonance circuit **21** and DC/DC converter **25**. The power receiving side rectification circuit **24** rectifies the AC electric power supplied from the power receiving side resonance circuit **21** to convert it to DC electric power and supplies the DC electric power to the DC/DC converter **25**. The power receiving side rectification circuit **24** is for example an AC/DC converter. Note that, between the power receiving side resonance circuit **21** and the power receiving side rectification circuit **24**, a filter circuit for eliminating noise of the AC electric power may also be provided.

[0045] The DC/DC converter **25** is electrically connected to the power receiving side rectification circuit **24**. The DC/DC converter **25** converts the voltage value of the DC electric power output from the power receiving side rectification circuit **24**. The DC/DC converter **25** is a back DC/DC converter (back converter), boost DC/DC converter (boost converter), or back boost DC/DC converter (back boost converter).

[0046] FIG. **2** is a circuit diagram showing the path of supply of electric power in the vehicle **1**. As shown in FIG. **2**, the vehicle **1** is provided with, in addition to the power receiving apparatus **2**, a battery **3**, motor **4**, and electric power supply circuit **5**.

[0047] The battery **3** stores electric power. The electric power stored in the battery **3** is consumed at the vehicle **1**. The battery **3** is a rechargeable secondary battery, for example, a lithium ion battery, nickel-hydrogen, etc. If electric power is supplied from the power receiving apparatus **2** to the battery **3**, the battery **3** is charged and the state of charge (SOC) of the battery **3** is restored. Further, the battery **3** can also be charged by an external power source other than the power supply apparatus **30** through a charging port provided at the vehicle **1**.

[0048] The motor **4** is an electric motor (for example, AC synchronous motor) and is driven using electric power as a power source. The output of the motor **4** is transmitted through a decelerator and shaft to the wheels. That is, the motor **4** outputs drive power of the vehicle **1**. In the present embodiment, the motor **4** is a motor-generator functioning as a motor and a generator. Therefore, at the time of deceleration of the vehicle **1**, the motor **4** is driven by operation of the vehicle **1**. The motor **4** uses the deceleration energy of the vehicle **1** to generate regenerative electric power. Further, in the present embodiment, the vehicle **1** is a battery electric vehicle (BEV) not mounting an internal combustion energy. Only the motor **4** functions as a drive source of the vehicle **1**.

[0049] The electric power supply circuit **5** is configured to supply electric power to the motor **4** from at least one of the battery **3** and the power receiving apparatus **2**. In the present embodiment, the voltage of the power receiving apparatus **2** is higher than the voltage of the battery **3**. As shown in FIG. 2, the electric power supply circuit **5** has an inverter **51**, switching elements **S1** to **S4**, diodes **D1** to **D4**, coils **L1**, **L2**, and capacitors **C1** to **C3**. Note that, the electric power supply circuit **5** may also be configured different from FIG. 2 so long as having a similar function.

[0050] The inverter **51** is electrically connected to the battery **3** and the power receiving apparatus **2** and motor **4**. The inverter **51** is supplied with electric power from at least one of the battery **3** and the power receiving apparatus **2**. The inverter **51** converts the DC electric power supplied to the inverter **51** to AC electric power and supplies the AC electric power to the motor **4**. Therefore, electric power is supplied to the motor **4** from at least one of the battery **3** and the power receiving apparatus **2** through the inverter **51**.

[0051] The electric power supply circuit **5** has a plurality of switching elements for switching the path of supply of electric power in the vehicle **1** (in particular, the path of supply of electric power to the motor **4**). In the present embodiment, it has four switching elements **S1** to **S4**. The switching elements **S1** to **S4** are, for example, comprised of IGBT (insulated gate bipolar transistors), MOS (metal oxide semiconductor) transistors, bipolar transistors, etc. As shown in FIG. 2, the switching elements **S1** to **S4** are connected in series with the inverter **51** and the motor **4**, while the diodes **D1** to **D4** are respectively connected antiparallel to the switching elements **S1** to **S4**.

[0052] Between the switching element **S1** and the switching element **S2**, the positive terminal of the power receiving apparatus **2** is connected through the coil **L2**. Between the switching element **S2** and the switching element **S3**, the positive terminal of the battery **3** is connected through the coil **L1**. Between the switching element **S3** and the switching element **S4**, the negative terminal of the power receiving apparatus **2** is connected.

[0053] The capacitor **C1** is connected in parallel with the battery **3**. The capacitor **C2** is connected in parallel with the power receiving apparatus **2**. The capacitor **C3** is connected in parallel with the inverter **51** and functions as a smoothing capacitor.

[0054] Further, the vehicle **1** is provided with an electronic control unit (ECU) **10** as a control device of the vehicle **1**. FIG. 3 is a schematic view of the configuration of the ECU **10** of the vehicle **1** and equipment connected to the ECU **10**. The ECU **10** performs various control of the vehicle **1**. The ECU **10** is one example of an electric power supply apparatus mounted in the vehicle **1**.

[0055] As shown in FIG. 3, the ECU **10** has a communication interface **11**, memory **12**, and processor **13**. The communication interface **11**, memory **12**, and processor **13** are connected with each other through signal wires.

[0056] The communication interface **11** is an interface circuit for connecting the ECU **10** to an

internal vehicle network compliant with the CAN (Controller Area Network) or other standard.

[0057] The memory **12** has, for example, a volatile semiconductor memory (for example, a RAM) and a nonvolatile semiconductor memory (for example, a ROM). The memory **12** stores programs to be run on the processor **13** and various data etc. used when various processings are performed by the processor **13**.

[0058] The processor **13** has one or more CPUs (central processing units) and their peripheral circuits and performs various processing. Note that, the processor **13** may further have processing circuits such as logical operation units and numerical operation units. As shown in FIG. 3, the above-mentioned DC/DC converter **25**, inverter **51**, and switching elements **S1** to **S4** are electrically connected to the ECU **10**. The ECU **10** controls the DC/DC converter **25**, inverter **51**, and switching elements **S1** to **S4** and controls the supply of electric power in the vehicle **1**, in particular the supply of electric power to the motor **4**. Further, the vehicle **1** is provided with a GNSS (global navigation satellite system) receiver **14**, map database **15**, sensors **16**, and communication device **17**. These are electrically connected to the ECU **10**.

[0059] The GNSS receiver **14** detects the current position of the vehicle **1** (for example, the latitude and longitude of the vehicle **1**) based on the positioning information obtained from a plurality of (for example, three or more) positioning satellites. Specifically, the GNSS receiver **14** captures a plurality of positioning satellites and receives radio waves emitted from the positioning satellites. Further, the GNSS receiver **14** calculates the distances to the positioning satellites based on the difference between the times of emission and times of reception of the radio waves and detects the current position of the vehicle **1** based on the distances to the positioning satellites and positions of the positioning satellites (orbital information). The output of the GNSS receiver **14**, that is, the current position of the vehicle **1** detected by the GNSS receiver **14**, is transmitted to the ECU **10**.

[0060] The map database **15** stores map information. The map information includes positional information etc. of a later explained power supply area. The ECU **10** acquires the map information from the map database **15**. Note that, the map database is provided at the outside of the vehicle **1** (for example, a server etc.) The ECU **10** may also acquire map information from the outside of the vehicle **1**.

[0061] The sensors **16** detect state quantities of the vehicle **1**. For example, the sensors **16** include a battery current sensor for detecting the input/output current of the battery **3** etc. The outputs of the sensors **16**, that is, the state quantities of the vehicle **1** detected by the sensors **16**, are transmitted to the ECU **10**.

[0062] The communication device **17** is a device for enabling communication between the vehicle **1** and the outside of the vehicle **1**. For example, the communication device **17** includes a short range wireless communication module (for example, DSRC (dedicated short range communication) vehicle-mounted device, Bluetooth™ module, etc.) for performing short range wireless communication and long range wireless communication module (for example, a data communication module (DCM) for performing long range wireless communication. The ECU **10** uses the communication device **17** to communicate with the power supply apparatus **30**.

[0063] FIG. 4 is a view showing one example of a power supply area in which a power transmitting coil **44** of the power supply apparatus **30** is installed. In the example of FIG. 4, three power transmitting coils **44** are arranged separated from each other along the direction of advance of the vehicle **1** on the same lane of the road. The range on the lane at which the plurality of power transmitting coils **44** is consecutively arranged corresponds to a power supply area. Note that, there may also be another number of power transmitting coils **44** installed in a single power supply area (for example, just one).

[0064] For example, when the vehicle **1** has approached a power supply area, the ECU **10** uses the communication device **17** to send a power supply request signal for requesting the supply of power to the vehicle **1** to the power supply apparatus **30**. If receiving a power supply request signal from the vehicle **1**, the controller **32** of the power supply apparatus **30** makes the power transmission

device **40** generate a power transmission use AC magnetic field. That is, if receiving a power supply request signal from the vehicle **1**, the controller **32** starts the supply of power by noncontact from the power supply apparatus **30** to the vehicle **1**.

[0065] By supplying electric power transmitted to the vehicle **1** by noncontact power supply to the battery **3**, it is possible to charge the battery **3** while the vehicle **1** is running. However, when the allowable charging electric power of the battery **3** is small, it is not possible to supply electric power transmitted to the vehicle **1** to the battery **3**. Therefore, it may be considered to directly supply the electric power which the power receiving apparatus **2** received to the motor **4** without going through the battery **3**. However, if there are two options of selection of the battery **3** and the power receiving apparatus **2** as the source of supply of electric power to the motor **4**, it is necessary to suitably selectively use these in accordance with the running environment etc. of the vehicle **1**.

[0066] Therefore, in the present embodiment, the ECU **10** selects the source of supply of electric power to the motor **4** from the battery **3** and the power receiving apparatus **2** in accordance with whether the vehicle **1** is running in a power supply area at which a power transmission coil **44** is installed. Due to this, in a vehicle **1** configured so as to be supplied with power by noncontact from a power transmitting coil **44** provided at the road, it is possible to suitably select the source of supply of electric power to the motor **4**.

[0067] In some embodiments, to reduce the loss of electric power in a vehicle **1**, electric power is directly supplied from the power receiving apparatus **2** to the motor **4** without going through the battery **3**. For this reason, in the present embodiment, the ECU **10** selects only the power receiving apparatus **2** as the source of supply of electric power to the motor **4** when the vehicle **1** is running in a power supply area and selects only the battery **3** as the source of supply of electric power to the motor **4** when the vehicle **1** is not running in a power supply area.

[0068] In the present embodiment, the ECU **10** controls the on/off states of the switching elements **S1** to **S4** so as to select the source of supply of electric power to the motor **4** from the battery **3** and the power receiving apparatus **2**. FIG. **5** is a view showing several states of the switching elements **S1** to **S4** set by the ECU **10** in the first embodiment.

[0069] In the present embodiment, the ECU **10** switches the states of the switching elements **S1** to **S4** between a first state and a second state. In the first state, when power is being supplied to the vehicle **1**, the switching elements **S2** and **S3** are turned off. As a result, electric power is supplied from the power receiving apparatus **2** to the inverter **51** and the motor **4** and the supply of electric power from the battery **3** to the inverter **51** and the motor **4** is cut off. That is, in the first state, the power receiving apparatus **2** is used as the source of supply of electric power to the motor **4**. Note that, in the first state, the switching elements **S1** and **S4** are set to any states (on or off).

[0070] In the second state, when power is not being supplied to the vehicle **1**, the switching elements **S1** and **S2** are turned on and the switching elements **S3**, **S4** are turned off. As a result, electric power is supplied from the battery **3** to the inverter **51** and the motor **4** and the supply of electric power from the power receiving apparatus **2** to the inverter **51** and the motor **4** is cut off. That is, in the second state, only the battery **3** is used as the source of supply of electric power to the motor **4**.

[0071] Further, even if the vehicle **1** had been positioned on a power supply area, sometimes power would not be normally supplied to the vehicle **1**. For this reason, even when the vehicle **1** is running in a power supply area, if trouble arises in the supply of power to the vehicle **1**, the ECU **10** selects only the battery **3** as the source of supply of electric power to the motor **4**. By doing this, it is possible to avoid trouble in the supply of power from causing power supplied to the motor **4** to become insufficient.

[0072] Below, referring to the flow chart of FIG. **6**, the flow of control explained above will be explained. FIG. **6** is a flow chart showing the control routine of the processing for supply of electric power in the first embodiment. The present control routine is repeatedly performed by the ECU **10** at predetermined intervals.

[0073] First, at step **S101**, the ECU **10** judges whether the vehicle **1** is running in a power supply area. For example, the ECU **10** performs this judgment by comparing the current position of the vehicle **1** acquired based on the output of the GNSS receiver **14** against the positional information of power supply areas stored in the map information of the map database **15**. Note that, ECU **10** may also judge that the vehicle **1** is running in a power supply area when the power receiving apparatus **2** of the vehicle **1** is receiving electric power.

[0074] If at step **S101** it was judged that the vehicle **1** was running in a power supply area, the present control routine proceeds to step **S101**. At step **S102**, the ECU **10** judges whether trouble has occurred in the supply of power to the vehicle **1**. For example, the ECU **10** judges that trouble has occurred in the supply of power to the vehicle **1** if at least one of the following abnormality conditions stands. If an abnormality condition stands, the supply of power from the power supply apparatus **30** to the vehicle **1** is suspended.

[0075] The first abnormality condition is an abnormality occurring in the power receiving apparatus **2** (for example, disconnection of the power receiving coil **22** etc.) For example, the ECU **10** judges that an abnormality has occurred in the power receiving apparatus **2** if electric power is not generated at the power receiving side resonance circuit **21** regardless of an AC magnetic field being emitted from the power transmitting coil **44**. In this case, an abnormality in power supply is notified from the vehicle **1** to the power supply apparatus **30** and the power supply apparatus **30** suspends supply of power to the vehicle **1**.

[0076] The second abnormality condition is positional deviation between the power receiving coil **22** and the power transmitting coil **44** in the vehicle width direction (horizontal deviation). For example, in the vehicle **1**, tracking coils for detecting positional deviation between the power receiving coil **22** and the power transmitting coil **44** in the vehicle width direction are provided at both sides of the power receiving side resonance circuit **21** in the vehicle width direction. In this case, the tracking coils output electric signals or weak AC electric power emitted from the power transmission device **40** as detection signals. The ECU **10** detects positional deviation based on the detection signals of the two tracking coils. The results of detection of the positional deviation are sent from the vehicle **1** to the power supply apparatus **30**. Note that, the power supply apparatus **30** may also detect positional deviation between the power receiving coil **22** and power transmitting coil **44** in the vehicle width direction and send the results of detection to the vehicle **1**.

[0077] The third abnormality condition is the presence of a foreign object on the road in the power supply area. For example, the power supply apparatus **30** is provided with a foreign object detection sensor for detecting a foreign object on the power transmitting coil **44** (for example, a photoelectric sensor, camera, metal detector, etc.) and transmits the results of detection of foreign objects to the vehicle **1**.

[0078] The fourth abnormality condition is a break in communication between the power supply apparatus **30** and the vehicle **1**. For example, the ECU **10** judges that there has been a break in communication between the power supply apparatus **30** and the vehicle **1** if a predetermined notification is not sent from the power supply apparatus **30** to the vehicle **1**.

[0079] Note that, conditions other than those mentioned above as abnormality conditions may also be used. Further, just some of the conditions mentioned above as abnormality conditions may also be used.

[0080] If it was judged at step **S102** that trouble had not arose in the supply of power to the vehicle **1**, the present control routine proceeds to step **S103**. At step **S103**, the ECU **10** sets the states of the switching elements **S1** to **S4** of the electric power supply circuit **5** to the first state. That is, the ECU **10** selects only the power receiving apparatus **2** as the source of supply of electric power to the motor **4**. After step **S103**, the present control routine ends.

[0081] On the other hand, if at step **S101** it was judged that the vehicle **1** was not running in a power supply area or if at step **S102**, it was judged that trouble had occurred in the supply of power to the vehicle **1**, the present control routine proceeds to step **S104**. At step **S104**, the ECU **10** sets

the states of the switching elements S1 to S4 of the electric power supply circuit 5 to the second state. That is, the ECU 10 selects only the battery 3 as the source of supply of electric power to the motor 4. After step S104, the present control routine ends.

Second Embodiment

[0082] The configuration and control of the vehicle according to the second embodiment are basically similar to the configuration and control of the vehicle according to the first embodiment except for the points explained below. For this reason, below, the second embodiment of the present disclosure will be explained focusing on the parts different from the first embodiment.

[0083] As explained above, when the vehicle 1 is running in a power supply area, the ECU 10 directly supplies electric power from the power receiving apparatus 2 to the motor 4. However, if the demanded torque of the vehicle 1 is large and the consumed electric power of the motor 4 is large, the electric power supplied to the motor 4 is liable to become insufficient with just the electric power received by the power receiving apparatus 2.

[0084] Therefore, in the second embodiment, when the vehicle 1 is running in a power supply area, the ECU 10 selects only the power receiving apparatus 2 as the source of supply of electric power to the motor 4 if the electric power consumed by the motor 4 is less than or equal to a predetermined value and selects the battery 3 and the power receiving apparatus 2 as the source of supply of electric power to the motor 4 if the electric power consumed by the motor 4 is greater than the predetermined value. By doing this, it is possible to keep the electric power supplied to the motor 4 from becoming insufficient in the power supply area.

[0085] FIG. 7 is a view showing a plurality of states of the switching elements S1 to S4 set by the ECU 10 in the second embodiment. In the second embodiment, the ECU 10 switches the states of the switching elements S1 to S4 among a first state to a third state. As explained above, in a first state, only the power receiving apparatus 2 is used as the source of supply of electric power to the motor 4. In a second state, only the battery 3 is used as the source of supply of electric power to the motor 4.

[0086] In the third state, when power is being supplied to the vehicle 1, the switching elements S1 to S4 are respectively alternately switched between on and off. When the switching elements S1, S2 are set to on, the switching elements S3, S4 are set to off. As a result, the voltage of the battery 3 is boosted by the coil L1 and capacitor C1 to the voltage of the power receiving apparatus 2 and electric power is supplied from both of the battery 3 and the power receiving apparatus 2 to the motor 4. That is, in the third state, the battery 3 and the power receiving apparatus 2 are used as the source of supply of electric power to the motor 4.

[0087] FIG. 8 is a flow chart of a control routine of the processing for supply of electric power in the second embodiment. The present control routine is repeatedly performed by the ECU 10 at predetermined intervals.

[0088] First, at step S201, in the same way as step S101 of FIG. 6, the ECU 10 judges whether the vehicle 1 is running in a power supply area. If it was judged that the vehicle 1 was running in a power supply area, the present control routine proceeds to step S202.

[0089] At step S202, in the same way as step S102 of FIG. 6, the ECU 10 judges whether trouble has occurred in the supply of power to the vehicle 1. If it was judged that trouble has not occurred in the supply of power to the vehicle 1, the present control routine proceeds to step S203.

[0090] At step S203, the ECU 10 judges whether the electric power consumed by the motor 4 is less than or equal to a predetermined value. The electric power consumed by the motor 4 is, for example, calculated based on the demanded torque of the vehicle 1, the electric power supplied to the motor 4, etc. The predetermined value is set to a predetermined fixed value or a value of less than or equal to the amount of power supplied to the vehicle 1 (for example, the amount of power supplied to the vehicle 1). The amount of power supplied to the vehicle 1 is notified from the power supply apparatus 30 to the vehicle 1 or is calculated based on the output of the current sensor, voltage sensor, etc. provided at the power receiving apparatus 2 of the vehicle 1.

[0091] On the other hand, if at step S203 it was judged that the electric power consumed by the motor 4 is less than or equal to the predetermined value, the present control routine proceeds to step S204. At step S204, the ECU 10 sets the states of the switching elements S1 to S4 of the electric power supply circuit 5 to the first state. That is, ECU 10 selects only the power receiving apparatus 2 as the source of supply of electric power to the motor 4. After step S204, the present control routine ends.

[0092] On the other hand, if at step S203 it was judged that the electric power consumed by the motor 4 is greater than the predetermined value, the present control routine proceeds to step S205. At step S205, the ECU 10 sets the states of the switching elements S1 to S4 of the electric power supply circuit 5 to the third state. That is, ECU 10 selects the battery 3 and the power receiving apparatus 2 as the source of supply of electric power to the motor 4. After step S205, the present control routine ends.

[0093] On the other hand, if at step S201 it is judged that the vehicle 1 is not running in a power supply area or if at step S202 it is judged that trouble has occurred in the supply of power to the vehicle 1, the present control routine proceeds to step S206. At step S206, the ECU 10 sets the states of the switching elements S1 to S4 of the electric power supply circuit 5 to the second state. That is, ECU 10 selects only the battery 3 as the source of supply of electric power to the motor 4. After step S206, the present control routine ends.

Third Embodiment

[0094] The configuration and control of the vehicle according to the third embodiment are basically similar to the configuration and control of the vehicle according to the second embodiment except for the points explained below. For this reason, below, the third embodiment of the present disclosure will be explained focusing on the parts different from the second embodiment.

[0095] As explained above, the motor 4 is supplied with electric power from at least one of the battery 3 and the power receiving apparatus 2. However, if the demanded voltage of the motor 4 is high, the voltage supplied to the motor 4 is liable to not reach the demanded voltage.

[0096] Therefore, in the third embodiment, when the demanded voltage of the motor 4 is greater than or equal to a predetermined value, the ECU 10 boosts the voltage of the electric power supplied to the inverter 51 and the motor 4. Due to this, it is possible to keep the voltage of the motor 4 from becoming insufficient.

[0097] FIG. 9 is a view showing the plurality of states of the switching elements S1 to S4 set by the ECU 10 in the third embodiment. In the third embodiment, the ECU 10 switches the states of the switching elements S1 to S4 among a first state to a sixth state. As explained above, in the first state, only the power receiving apparatus 2 is used as the source of supply of electric power to the motor 4. In a second state, only the battery 3 is used as the source of supply of electric power to the motor 4. Further, in a third state, voltage of the battery 3 is boosted to the voltage of the power receiving apparatus 2, and the battery 3 and the power receiving apparatus 2 are used as the source of supply of electric power to the motor 4.

[0098] In a fourth state, when the vehicle 1 is being supplied with power, the switching elements S1 to S4 are respectively alternately switched between on and off. When the switching elements S1, S4 are set to on, the switching elements S2, S3 are set to off. As a result, the voltage of the power receiving apparatus 2 is boosted by the coil L2 and capacitor C2 and the boosted electric power is supplied from the power receiving apparatus 2 to the motor 4. That is, in the fourth state, the voltage of the power receiving apparatus 2 is boosted and only the power receiving apparatus 2 is used as the source of supply of electric power to the motor 4.

[0099] In a fifth state, when the vehicle 1 is not being supplied with power, the switching elements S1 to S4 are respectively alternately switched between on and off. When the switching elements S1, S2 are set to on, the switching elements S3, S4 are set to off. As a result, the voltage of the battery 3 is boosted by the coil L1 and capacitor C1 and the boosted electric power is supplied from the battery 3 to the motor 4. That is, in the fifth state, the voltage of the battery 3 is boosted and

only the battery 3 is used as the source of supply of electric power to the motor 4.

[0100] When, in the sixth state, power is supplied to the vehicle 1, the switching elements S1, S3 are turned on and the switching elements S2, S4 are turned off. As a result, the battery 3 and the power receiving apparatus 2 are connected in series and high voltage electric power is supplied from the battery 3 and the power receiving apparatus 2 to the motor 4. That is, in the sixth state, as the source of supply of electric power to the motor 4, the series connected battery 3 and the power receiving apparatus 2 are used. In the sixth state, compared with the fourth state in which loss of electric power occurs due to a boost operation, it is possible to more efficiently supply high voltage electric power to the motor 4.

[0101] FIG. 10 is a flow chart showing a control routine of the processing for supply of electric power in the third embodiment. The present control routine is repeatedly performed by the ECU 10 at predetermined intervals.

[0102] First, at step S301, in the same way as step S101 of FIG. 6, the ECU 10 judges if the vehicle 1 is running in a power supply area. If it is judged that the vehicle 1 is running in a power supply area, the present control routine proceeds to step S302.

[0103] At step S302, in the same way as step S102 of FIG. 6, the ECU 10 judges if trouble has occurred in the supply of power to the vehicle 1. If it is judged that trouble has not occurred in the supply of power to the vehicle 1, the present control routine proceeds to step S303.

[0104] At step S303, the ECU 10 judges if the demanded voltage of the motor 4 is greater than or equal to a predetermined value. The demanded voltage of the motor 4 is, for example, calculated based on the speed and torque of the motor 4. If it is judged that the demanded voltage of the motor 4 is greater than or equal to the predetermined value, the present control routine proceeds to step S304.

[0105] At step S304, the ECU 10 judges if the SOC of the battery 3 is greater than or equal to a predetermined value. The SOC of the battery 3 is, for example, calculated by cumulatively adding the input/output currents of the battery 3 detected by the battery current sensor or is calculated using a status estimation method such as a Kalman filter. The predetermined value is, for example, set to 30% to 80%.

[0106] If at step S304 it was judged that the SOC of the battery 3 was less than the predetermined value, the present control routine proceeds to step S305. At step S305, the ECU 10 sets the states of the switching elements S1 to S4 of the electric power supply circuit 5 to the fourth state so as to supply high voltage electric power to the motor 4 without consuming the electric power of the battery 3. That is, the ECU 10 selects only the power receiving apparatus 2 as the source of supply of electric power to the motor 4 to boost the voltage of the power receiving apparatus 2. After step S305, the present control routine ends.

[0107] On the other hand, if at step S304 it was judged that the SOC of the battery 3 was greater than or equal to the predetermined value, the present control routine proceeds to step S306. At step S306, the ECU 10 sets the states of the switching elements S1 to S4 of the electric power supply circuit 5 to a sixth state. That is, the ECU 10 selects the power receiving apparatus 2 and the battery 3 connected in series as the source of supply of electric power to the motor 4. After step S306, the present control routine ends.

[0108] Further, if at step S303 it was judged that the demanded voltage of the motor 4 is less than a predetermined value, the present control routine proceeds to step S307. At step S307, in the same way as step S203 of FIG. 8, the ECU 10 judges whether the consumed electric power of the motor 4 is less than or equal to the predetermined value.

[0109] If at step S307 it was judged that the consumed electric power of the motor 4 was less than or equal to a predetermined value, the present control routine proceeds to step S308. At step S308, the ECU 10 sets the states of the switching elements S1 to S4 of the electric power supply circuit 5 to the first state. That is, the ECU 10 selects only the power receiving apparatus 2 as the source of supply of electric power to the motor 4. After step S308, the present control routine ends.

[0110] On the other hand, if at step S307 it was judged that the consumed electric power of the motor 4 was greater than the predetermined value, the present control routine proceeds to step S309. At step S309, the ECU 10 sets the states of the switching elements S1 to S4 of the electric power supply circuit 5 to the third state. That is, the ECU 10 selects the battery 3 and the power receiving apparatus 2 as the source of supply of electric power to the motor 4. After step S309, the present control routine ends.

[0111] Further, if at step S301 it was judged that the vehicle 1 was not running in a power supply area or if at step S302 it was judged that trouble occurred in the supply of power to the vehicle 1, the present control routine proceeds to step S310. At step S310, in the same way as step S303, the ECU 10 judges if the demanded voltage of the motor 4 is greater than or equal to a predetermined value. If it was judged that the demanded voltage of the motor 4 was less than the predetermined value, the present control routine proceeds to step S311. At step S311, the ECU 10 sets the states of the switching elements S1 to S4 of the electric power supply circuit 5 to the second state. That is, the ECU 10 selects only the battery 3 as the source of supply of electric power to the motor 4. After step S311, the present control routine ends.

[0112] On the other hand, if at step S310 it was judged that the demanded voltage of the motor 4 was greater than or equal to the predetermined value, the present control routine proceeds to step S312. At step S312, the ECU 10 sets the states of the switching elements S1 to S4 of the electric power supply circuit 5 to the fifth state. That is, the ECU 10 selects only the battery 3 as the source of supply of electric power to the motor 4 and boosts the voltage of the battery 3. After step S312, the present control routine ends.

Other Embodiments

[0113] Above, embodiments according to the present disclosure were explained, but the present disclosure is not limited to these embodiments and can be corrected and changed in various ways within the language of the claims. For example, the vehicle 1 may also be a hybrid electric vehicle (HEV) provided with an internal combustion engine and motor as the drive sources of the vehicle 1 or a plug-in hybrid electric vehicle (PHEV).

[0114] Further, when the states of the switching elements S1 to S4 are set to the first state, that is, when only the power receiving apparatus 2 is selected as the source of supply of electric power to the motor 4, if the amount of power supplied to the vehicle 1 is greater than the consumed electric power of the motor 4, the ECU 10 may supply electric power from the power receiving apparatus 2 to the motor 4 and the battery 3. Due to this, it is possible use excess electric power to charge the battery 3 and possible to keep down waste of electric power supplied to the vehicle 1. In this case, when the states of the switching elements S1 to S4 are set to the first state, the ECU 10 temporarily turns the switching element S2 on to thereby supply electric power from the power receiving apparatus 2 to the battery 3.

REFERENCE SIGNS LIST

[0115] 1 vehicle [0116] 2 power receiving apparatus [0117] 22 power receiving coil [0118] 3 battery [0119] 4 motor [0120] 5 electric power supply circuit [0121] 10 electronic control unit (ECU) [0122] 30 power supply apparatus [0123] 40 power transmission device [0124] 44 power transmitting coil

Claims

1. A vehicle, the vehicle comprising: a battery configured to store electric power; a power receiving apparatus provided with a power receiving coil for receiving electric power from a power transmitting coil provided at a road; a motor configured to output drive power of the vehicle; an electric power supply circuit configured to supply electric power from at least one of the battery and the power receiving apparatus to the motor; and a control device configured to control the supply of electric power to the motor, wherein the control device is further configured to select a

source of supply of electric power to the motor from the battery and the power receiving apparatus in accordance with whether the vehicle is running in a power supply area at which the power transmitting coil is provided.

2. The vehicle according to claim 1, wherein the control device is further configured to select only the power receiving apparatus as the source of supply of electric power when the vehicle is running in the power supply area.
 3. The vehicle according to claim 1, wherein the control device is further configured to select only the power receiving apparatus as the source of supply of electric power when the vehicle is running in the power supply area and a consumed electric power of the motor is less than or equal to a predetermined value and to select the battery and the power receiving apparatus as the source of supply of electric power when the consumed electric power is greater than the predetermined value.
 4. The vehicle according to claim 2, wherein the control device is further configured to select only the battery as the source of supply of electric power even when the vehicle is running in the power supply area, when trouble arises in supply of power to the vehicle.
 5. The vehicle according to claim 1, wherein the control device is further configured to supply electric power from the power receiving apparatus to the motor and the battery when selecting only the power receiving apparatus as the source of supply of electric power and the amount of power supplied to the vehicle is greater than the electric power consumed by the motor.
 6. The method of supply of electric power to a motor for outputting drive power of a vehicle, in which electric power supply method, the vehicle comprising: a battery for storing electric power: a power receiving apparatus having a power receiving coil for receiving electric power from a power transmitting coil provided at a road; and an electric power supply circuit configured so as to supply electric power from at least one of the battery and the power receiving apparatus to the motor, the electric power supply method comprising selecting a source of supply of electric power to the motor from the battery and the power receiving apparatus in accordance with whether the vehicle is running in a power supply area at which the power transmitting coil is provided.
 7. An electric power supply apparatus mounted in a vehicle, wherein, the vehicle comprises: a battery for storing electric power; a power receiving apparatus having a power receiving coil for receiving electric power from a power transmitting coil provided at a road: a motor for outputting drive power of the vehicle; and an electric power supply circuit configured so as to supply electric power from at least one of the battery and the power receiving apparatus to the motor, and the electric power supply apparatus is configured to select a source of supply of electric power to the motor from the battery and the power receiving apparatus in accordance with whether the vehicle is running in a power supply area at which the power transmitting coil is provided.
 8. The electric power supply apparatus according to claim 7, further configured to select only the power receiving apparatus as the source of supply of electric power when the vehicle is running in the power supply area.
 9. The electric power supply apparatus according to claim 7, further configured to select only the power receiving apparatus as the source of supply of electric power when the vehicle is running in the power supply area and a consumed electric power of the motor is less than or equal to a predetermined value and to select the battery and the power receiving apparatus as the source of supply of electric power when the consumed electric power is greater than the predetermined value.
 10. The electric power supply apparatus according to claim 8, wherein the vehicle selects only the battery as the source of supply of electric power even when the vehicle is running in the power supply area, when trouble arises in supply of power to the vehicle.
 11. The electric power supply apparatus according to claim 7, further configured to supply electric power from the power receiving apparatus to the motor and the battery when selecting only the power receiving apparatus as the source of supply of electric power and the amount of power supplied to the vehicle is greater than the electric power consumed by the motor.
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