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CONTACTLESS POWER SUPPLY SYSTEM, POWER TRANSMISSION APPARATUS, POWER RECEPTION APPARATUS

Abstract

A contactless power supply system is provided with a transmission apparatus, and a reception apparatus to which the transmission apparatus supplies power in a contactless manner. The reception apparatus includes: a secondary resonant circuit, a rectifier circuit, an immittance circuit, a load, a protection switch changing the state between a conductive state and a non-conductive state, thereby causing the secondary resonant circuit to be in a non-resonant state, and a secondary side control circuit that sets the protection switch to be in the conductive state or the non-conductive state. The primary side control circuit changes the impedance of the variable impedance element, using a detection value of the primary detection circuit which changes depending on the state of the protection switch being set to be in the conductive state or the non-conductive state, thereby causing the reception apparatus to be in the standby state from the transmission state.

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Background/Summary

CROSS-REFERENCE OF RELATED APPLICATIONS [0001] This application is the U.S. bypass application of International Application No. PCT/JP2023/038237 filed on Oct. 24, 2023, which designated the U.S. and claims priority to Japanese Patent Application 2022-191017 filed on Nov. 30, 2022, and the contents of both of these are incorporated herein by reference.

BACKGROUND
Technical Field
[0002] The present disclosure relates to a contactless power supply apparatus, a power transmission apparatus, a power reception apparatus.
Description of the Related Art
[0003] Conventionally, a technique is disclosed for a power reception apparatus supplied with power from a power transmission apparatus in a contactless manner, for protecting a load to be supplied with the received power when an abnormality occurs. According to the above-mentioned technique, a transistor included in a rectifier is controlled to be ON, and thereafter, a relay disposed on a current path from a resonator coil to the rectifier is controlled to be opened, thereby protecting the load.
[0004] Since the power transmission apparatus continues to transmit power even after the power reception apparatus stops receiving the power, a power loss possibly occurs in the power transmission apparatus.
SUMMARY
[0005] According to a first aspect of the present disclosure, a contactless power supply system is provided to include a transmission apparatus and a reception apparatus to which the transmission apparatus supplies power in a contactless manner. The reception apparatus includes: a secondary resonant circuit including a secondary coil to be magnetically coupled with the primary coil, and a secondary capacitor; a rectifier circuit that rectifies AC power outputted from the secondary resonant circuit; an immittance circuit connected between the rectifier circuit and the secondary resonant circuit; a load to which a DC power outputted from the rectifier circuit is supplied; a protection switch of which the state is changed to be in a conductive state or a non-conductive state, thereby causing the secondary resonant circuit to be in a non-resonant state; and a secondary side control circuit that sets the state of the protection switch to be in either the conductive state or the non-conductive state. The primary side control circuit is configured to change the impedance of the variable impedance element, using a detection value of the primary detection circuit which changes depending on the state of the protection switch being set to be in the conductive state or

the non-conductive state, thereby causing the reception apparatus to be in the standby state from the transmission state.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

[0006] The above-described objects and other objects, features and advantages of the present disclosure will be clarified further by the following detailed description with reference to the accompanying drawings. The drawings are:

[0007] FIG. **1** is a diagram showing an overall configuration of a contactless power supply system;

[0008] FIG. **2** is a circuit diagram showing a contactless power supply system according to a first embodiment;

[0009] FIG. **3** is a flowchart showing a power supply sequence according to the first embodiment;

[0010] FIG. **4** is a circuit diagram showing a contactless power supply system according to a second embodiment;

[0011] FIG. **5** is a flowchart showing a power supply sequence according to the second embodiment;

[0012] FIG. **6** is a circuit diagram showing a contactless power supply system according to a third embodiment;

[0013] FIG. **7** is a flowchart showing a power supply sequence according to the third embodiment;

[0014] FIG. **8** is a circuit diagram showing a contactless power supply system according to a fourth embodiment;

[0015] FIG. **9** is a circuit diagram showing a contactless power supply system according to a fifth embodiment; and

[0016] FIG. **10** is a flowchart showing a power supply sequence according to the fifth embodiment.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0017] Conventionally, a technique is disclosed for a power reception apparatus supplied with power from a power transmission apparatus in a contactless manner, for protecting a load to be supplied with the received power when an abnormality occurs (e.g. JP-2022-533250). According to the above-mentioned patent literature JP-2022-533250, a transistor included in a rectifier is controlled to be ON, and thereafter, a relay disposed on a current path from a resonator coil to the rectifier is controlled to be opened, thereby protecting the load. Since the power transmission apparatus continues to transmit power even after the power reception apparatus stops receiving the power, a power loss possibly occurs in the power transmission apparatus.

[0018] Hereinafter, embodiments of the present disclosure will be described.

A. First Embodiment

A1. Configuration of Contactless Power Supply System

[0019] As shown in FIG. **1**, the contactless power supply system **1** is provided with a power transmission apparatus **10** and a power reception apparatus **80**. According to the present embodiment,

the transmission apparatus **10** is buried under the road RS. The reception apparatus **80** is mounted on a vehicle VE as a mobile body travelling on the road RS. The reception apparatus **80** is supplied with power from the transmission apparatus **10** during the traveling of the vehicle VE. Here, ‘during traveling’ includes a case where the vehicle VE is moving and a case where the vehicle is stopped when waiting for a traffic light to change. The vehicle VE is configured as an electric vehicle or a hybrid vehicle.

[0020] The transmission apparatus **10** includes a primary resonant circuit **12** having a primary coil L**1** and an AC power source **11** that supplies power to the primary resonant circuit **12**. The AC power source **11** supplies power to a plurality of primary resonant circuits **12**. The plurality of primary coils L**1** are arranged along a direction with which the road RS extends.

[0021] The mobile body having the reception apparatus mounted thereon is not limited to the vehicle VE traveling on the road RS, but may be an AGV (automatic guided vehicle) or a mobile robot. Further, the transmission apparatus **10** may be installed not only under the road RS but also installed on a sidewalk next to the road RS or in a parking lot or on a route where the AGV travels.

[0022] The reception apparatus **80** is provided with a battery **84** as a load, an auxiliary battery **94**, a rectifier circuit **83**, a secondary resonant circuit **81** having a secondary coil L**2** magnetically coupled to a primary coil L**1**, a DC-DC converter **92**, an inverter **91**, a motor generator **93**, an auxiliary equipment **95** and a reception side control unit **96**. According to the present embodiment, the secondary coil L**2** is disposed on a lower surface of the vehicle VE, facing the primary coil L**1**.

[0023] The rectifier circuit **83** is connected to the secondary resonant circuit **81**. During the reception state, the rectifier circuit **83** rectifies the AC power received by the secondary resonant circuit **81** and supplies the rectified DC power to the battery **84**, the DC-DC converter **92** and the inverter **91**.

[0024] The battery **84** is a secondary battery charged by the supplied DC power. The inverter **91** utilizes the supplied DC power to drive the motor generator **93**. The motor generator **93** operates as a three-phase AC motor to produce a driving force for travelling. In addition, the motor generator **93** operates as a generator when the vehicle VE decelerates to regenerate the power. The regenerated three-phase AC power is converted to DC power by the inverter **91** and is used for a charging of the battery **84**.

[0025] The DC-DC converter **92** steps-down the DC power supplied from the rectifier circuit **83** and supplies the stepped-down DC power to the auxiliary battery **94** and the auxiliary equipment **95**. The auxiliary equipment **95** includes an air-conditioner, an electric power steering apparatus, peripheral apparatuses of the vehicle VE such as a head lamp, a direction indicator and a wiper, and an accessory of the vehicle VE. The auxiliary battery **94** serves as a secondary battery for driving the auxiliary battery **95**.

[0026] The reception side control unit **96** controls respective units such as the inverter **91** in the reception apparatus **80**. The reception side control unit **96** is configured at least including an ECU (engine control unit). Note that the ECU may be configured of a single microcontroller or may be configured including a plurality of microcontrollers. A case where the ECU is configured including a plurality of microcontroller refers to a case where a microcontroller that controls a configuration such as the motor generator **93** related to a driving of the vehicle VE, and a microcontroller that controls a configuration related to the battery **84** such as the rectifier circuit **83** are included.

A2. Circuit Configuration of Contactless Power Supply System:

[0027] As shown in FIG. **2**, the transmission apparatus **10** is provided with, in addition to the above-described configuration, a primary capacitor C**1**, a primary side control circuit **13**, a magnetic flux detection circuit **14** as a primary detection circuit. In FIG. **2**, among the plurality of primary resonant circuits **12** connected to the AC power source **11**, only one of the primary resonant circuit **12** is shown and the illustration of other primary resonant circuits **12** are omitted.

[0028] The AC power source **11** applies an AC power having a predetermined operating frequency to the primary resonant circuit **12**. According to the present embodiment, the operating frequency is 85 KHz. The primary capacitor C**1** as a variable impedance element is utilized to cause the primary resonant circuit **12** to be in a resonant state with the operating frequency and cause the primary resonant circuit **12** to be in a non-resonant state with the operating frequency. The primary capacitor C**1** is connected to a portion between the primary coil L**1** and the AC power source **11**. The primary capacitor C**1** changes the state of the transmission apparatus **10** between a standby state and a transmission state which will be described later.

[0029] According to the present embodiment, the primary capacitor C**1** is configured to be capable of changing the capacitance between a first capacitance and a second capacitance smaller than the first capacitance. Then, the capacitance of the primary capacitor C**1** is changed, in response to a switch signal Sig**1** outputted from the primary side control circuit **13**, to be either the first capacitance or the second capacitance. In the case where the primary coil L**1** and the secondary coil are magnetically coupled to each other and the primary capacitor C**1** has the first capacitance, the primary resonant circuit **12** is in a resonant state with the operating frequency. That is, the first capacitance of the primary capacitor C**1** is set such that the resonant frequency of the primary resonant circuit **12** is the same as the operating frequency. However, in the case where the primary capacitance C**1** has the second capacitance, since the resonant frequency of the primary resonant circuit **12** deviates from the operating frequency, the primary resonant circuit **12** is in the non-resonant state with the operating frequency

[0030] The primary coil L**1** and the primary capacitor C**1** are connected in series to constitute the primary resonant circuit **12**. The magnetic flux detection circuit **14** detects a magnitude of the magnetic flux in the vicinity of the primary coil L**1**. Specifically, the magnetic flux detection circuit **14** incorporates a detection coil Lsp disposed in the vicinity of the secondary coil L**2**, and detects the magnitude of the magnetic flux density using a change in the current flowing through the detection coil Lsp. The magnetic flux detection circuit **14** outputs a signal indicating the magnitude of the detected magnetic flux to the primary side control circuit **13**.

[0031] The primary side control circuit **13** uses a signal outputted from the magnetic flux detection circuit **14**, thereby outputting the switch signal Sig**1** to the primary capacitor C**1**.

[0032] Note that the primary detection circuit is not limited to the magnetic detection circuit **14** that detects a magnitude of the magnetic flux density, but may be a sensor capable of detecting a magnitude of the magnetic flux interlinking with the primary coil L**1**. Specifically, the primary detection circuit may be a current sensor that detects current flowing through the primary coil L**1** or a voltage sensor that detects voltage of the primary coil L**1**. Note that ‘detecting magnitude of magnetic flux interlinking with the primary coil L**1**’ refers to not only a case where entire magnetic flux interlinking with the primary coil L**1** is detected but also a case where a part of the magnetic flux interlinking with the primary coil L**1** is detected according to the present embodiment.

[0033] The reception apparatus **80** includes, in addition to the above-described configurations, secondary capacitors C**2** and C**3**, an immittance circuit **82**, a secondary side control circuit **85** and an abnormality detection circuit **86**. The secondary capacitor C**2** is series-connected to one end of the secondary coil L**2** and the secondary capacitor C**3** is series-connected to the other end of the secondary coil L**2**, thereby constituting the secondary resonant circuit **81**. As another embodiment of the secondary resonant circuit **81**, the secondary resonant circuit **81** may include either the secondary capacitor C**2** or the secondary capacitor C**3**.

[0034] The immittance circuit **82** is connected to a portion between the secondary resonant circuit **81** and the rectifier circuit **83**. In the case where an AC power having the resonant frequency of the immittance circuit **82** is transmitted to the immittance circuit **82**, the immittance circuit **82** serves as an impedance-admittance conversion unit. In the case where an AC power having a frequency different from the resonant frequency of the immittance **82** is transmitted to the immittance circuit **82**, the immittance circuit **82** serves as a low-pass filter.

[0035] According to the present embodiment, the immittance circuit **82** includes coils L**3** to L**6** and a capacitor C**4**. The coils L**3** and L**4** are series-connected to a first feeding line N**1** connected to one end of the secondary coil L**2**. The coils L**5** and L**6** are series-connected to a second feeding line N**2** connected to the other end of the secondary coil L**2**. The capacitor C**4** is connected to a connection point between the coil L**3** and the coil L**4** and a connection point between the coil L**5** and the coil L**6**, and is connected in parallel to the coil L**2**.

[0036] The secondary resonant circuit **81** further includes a protection switch SW**1**. The protection switch SW**1** is connected in parallel to the secondary coil L**2**. Thus, compared to a case where the protection switch SW**1** is series-connected to the secondary coil L**2**, that is, the protection switch SW**1** is inserted to the first feeding line N**1** or the second feeding line N**2**, a power loss can be reduced and the rated current of the protection switch SW**1** can be smaller. The conductive state of

the protection switch SW**1** causes the secondary resonant **81** to be in a non-resonant state. According to the present embodiment, the protection switch SW**1** is accomplished by a bi-directional switch configured of two MOSFETs of which the respective source terminals are connected together. Thus, the size of the protection switch SW**1** can be reduced.
[0037] The secondary side control circuit **85** changes the state of the protection switch SW**1** between the conductive state and the non-conductive state. According to the present embodiment, the secondary side control circuit **85** changes the voltage of the signal Sig**2** to be inputted to the gate terminals of two MOS FETs that constitutes the protection switch SW**1**, thereby changing the state of the protection switch SW**1**.
[0038] The rectifier circuit **83** is configured of a diode-bridge circuit.
[0039] The abnormality detection circuit **86** detects a state of abnormality in the reception apparatus **80**. Specifically, the abnormality detection circuit **86** includes a voltage sensor (not shown) that detects the voltage of the battery **84**, determines an abnormality in the case where the voltage of the battery **84** is outside a predetermined voltage range and outputs an abnormality signal to a secondary side control circuit **85**.
[0040] The reception side control unit **96** outputs a stop signal to the secondary side control circuit **85** when inhibiting a power supply to the battery **84** from the secondary resonant circuit **81**. The reception side control unit **96** outputs a stop signal when determining that the state of the battery **84** is not appropriate for charging.
[0041] In the case where the primary coil L**1** and the secondary coil L**2** are magnetically coupled, the resonant frequency of the primary resonant circuit **12** and the resonant frequency of the second resonant circuit **81** are set to be substantially the same. Thus, with a magnetic field resonant between the primary coil L**1** and the secondary coil L**2**, contactless power supply can be accomplished for the reception apparatus **80**. As described above, the DC power outputted from the secondary resonant circuit **81** is rectified by the rectifier circuit **83** and the rectified DC power is supplied to the battery **84**.
A3. Power Supply Sequence
[0042] The primary coils L**1** are arranged in a direction where the road RS extends, the secondary coil L**2** is supplied with power from the closest primary coil L**1** in a contactless manner, that is, contactless power supply.
[0043] The transmission apparatus **10** causes a standby current to flow through the primary coil L**1** in the standby state, thereby producing magnetic flux at the primary coil L**1**. When the secondary coil L**2** approaches the primary coil L**1**, the reception apparatus **80** utilizes a secondary side detection circuit (not shown) to detect magnetic flux produced by the primary coil L**1**. The reception apparatus **80** produces, when detecting magnetic flux produced by the primary coil L**1**, activation flux at step S**1** shown in FIG. **3**. Specifically, the reception apparatus **80** applies AC power to a flux-producing coil (not shown). Thus, the flux-producing coil produces magnetic flux.
[0044] Note that the method executed by the reception apparatus **80** to detect the closest primary coil L**1** is not limited to the above-described method. For example, a camera included in the reception apparatus **80** may capture an identifier indicated at a portion in the vicinity of the primary coil L**1**, thereby detecting the closest primary coil L**1**.
[0045] The primary side control circuit **13** changes, when determining that the magnetic flux density indicated by a signal outputted from the magnetic flux detection circuit **14** is larger than a threshold, the impedance of the primary capacitance C**1** as a variable impedance element at step S**3** shown in FIG. **3**. Specifically, the primary side control circuit **13** outputs the switch signal Sig**1** to the primary capacitor C**1**. Thus, the capacitance value of the primary capacitor C**1** is changed to the first capacitance from the second capacitance. Thus, the primary side resonant circuit **12** is in a resonant state at the operating frequency, activating the transmission state that causes the transmission current to flow through the primary coil L**1**, thereby starting the power supply operation. Thus, the transmission apparatus **10** changes the state from the standby state to the

transmission state in the case where the magnetic flux detection circuit **14** detects an increase in the magnetic flux in the vicinity of the primary coil L**1**. The transmission apparatus **10** changes the state from the standby state to the transmission state at a time when the capacitance value of the primary capacitor C**1** is changed. Similarly, the reception apparatus **80** changes the state from the non-power reception state to the power reception state at a time when the capacitance value of the primary coil L**1** is changed. During the power reception state of the reception apparatus **80**, the protection switch SW**1** is set to be in a non-conductive state.

[0046] As shown in FIG. **3**, the secondary side control circuit **85** of the reception apparatus **80** determines whether a stop signal as a power supply stop signal is received at step S**5** after activating the power reception. When determining that the stop signal is received, the secondary side control circuit **85** determines, at step S**7**, whether an abnormality signal as a power supply stop signal is received. When determining that the abnormality signal is not received, the secondary side control circuit **85** returns to step S**5**.

[0047] On the other hand, when determining that the stop signal is received at step S**5** and determining that an abnormality signal is received at step S**7**, the secondary side control circuit **85** sets the protection switch SW**1** to be in the conductive state at step S**15**. In more detail, the secondary side control circuit **85** changes the state of the protection switch SW**1** from the non-conductive state to the conductive state. Specifically, the secondary side control circuit **85** outputs a high level of signal Sig**2** to the protection switch SW**1**. Thus, the protection switch SW**1** is in the conductive state and one end of the secondary coil L**1** and the other end of the secondary coil L**2** are short-circuited. Hence, the impedance of the secondary resonant circuit **81** becomes higher and the current flowing through the secondary coil L**2** becomes smaller. Accordingly, since the current supplied to the battery **84** decreases, the battery **84** can be protected. Also, one end and the other end of the secondary coil L**2** are short-circuited, thereby causing the secondary coil L**2** to serve as a cancel coil that cancels the magnetic flux produced by the primary coil L**1**.

[0048] The impedance Z of the secondary resonant circuit **81** when the protection switch SW**1** is in a non-conductive state is expressed by an equation (1), where an inductance of the secondary coil L**2** is L, the capacitance of the secondary capacitor C**2** is C/2, the capacitance of the secondary capacitor C**3** is C/2, and the resistance of the resistance component of the secondary resonant circuit **81** is r.

[00001] $Z = r + j(\ \ L - 1/\omega C)$ (1)

[0049] Note that j indicates an imaginary unit and @ indicates an angular frequency in the equation (1). The frequency at which the imaginary unit j in the equation (1) is 0 refers to the resonant frequency. When the protection switch SW**1** is in a conductive state, the impedance value of the secondary resonant circuit **81** is different from that obtained from the equation (1).

[0050] Hence, in the case where AC power having the resonant frequency is transmitted to the secondary resonant circuit **81**, the imaginary unit in the equation (1) is not 0, and the impedance of the secondary resonant circuit **81** becomes higher. Therefore, the current flowing through the secondary coil L**2** is lower than a current flowing through the secondary coil L**2** in the case where the protection switch SW**1** is in a non-conductive state.

[0051] The input impedance of the primary resonant circuit **12** increases in response to an increase in the impedance of the secondary resonant circuit **81**. Thus, the current flowing through the primary coil L**1** decreases and the magnetic flux density detected by the magnetic flux density detection circuit **14** becomes smaller. The primary side control circuit **13** outputs, at step S**19**, the switch signal Sig**1** that changes the capacitance of the primary capacitor C**1** to be the second capacitance, when determining, at step S**17**, that the detection value Bd of the magnetic flux density indicated by a signal outputted from the magnetic flux detection circuit **14** is smaller than a reference magnetic flux density Bth. Thus, the primary resonant circuit **12** is in the non-resonant state at the operating frequency and the power transmission is stopped. Hence, even in the case where the reception apparatus **80** stops the power reception, without relying on a communication, the power transmission can be stopped. Thus, power consumption which does not contribute the power supply in the transmission apparatus **10** can be reduced.

[0052] According to the first embodiment described above, the reception apparatus **80** includes a protection switch SW**1**. Hence, the protection switch SW**1** is used to protect the battery **84** by lowering the current flowing through the secondary coil L**2** when the reception apparatus **80** is in an abnormality state. During the power transmission state, when the magnetic flux in the vicinity of the primary coil L**1** is small, the primary side control circuit **13** changes the capacitance of the primary capacitor C**1** to change the impedance of the primary resonant circuit **12** to be higher, thereby changing the state to be the standby state. Thus, power consumption which does not contribute the power supply in the transmission apparatus **10** can be reduced.

B. Second Embodiment

[0053] As shown in FIG. **4**, the contactless power supply system **201** differs from the above-described first embodiment in that the configuration of the primary resonant circuit **12**, the configuration of the immittance circuit **282**, the configuration of the rectifier circuit **283**, configuration of the protection switch and the power supply sequence are different. For configurations and process steps same as those in the first embodiment, the same reference symbols are applied and detailed explanation will be omitted.

[0054] The primary resonant circuit **212** includes a first capacitor C**21**, a second capacitor C**22** and a primary coil L**1**. The first capacitor C**21** and the second capacitor C**22** are connected in series to the primary coil L**1**. The capacitance of the first capacitor C**21** is smaller than the capacitance of the second capacitor C**22**. Further, the transmission apparatus **210** includes a switch SW**21** that bypasses the first capacitor C**21**. During a power-transmission state of the transmission apparatus **210**, the switch SW**21** as a variable impedance element is set to be in a conductive state. During a standby state of the transmission apparatus **210**, the switch SW**21** is set to be in a non-conductive state. In the case where the switch SW**21** is set to be in the conductive state, the capacitance of the second capacitor C**22** is set to be a value that allows the primary coil L**1** to be in a resonant state at the operating frequency. Once the switch SW**21** is set to be in the non-conductive state, the impedance of the primary resonant circuit **212** becomes higher and a standby current smaller than the transmission current flows through the primary coil L**1**.

[0055] According to the present embodiment, instead of the magnetic flux detection circuit **14** of the first embodiment, a voltage sensor M**1** as a primary detection circuit is provided. The voltage sensor M**1** is used to detect a magnitude of magnetic flux interlinking with the primary coil. Specifically, the voltage sensor M**1** detects the voltage of the second capacitor C**22** and outputs a signal indicating the detection value to the primary side control circuit **13**. The detection value of the voltage sensor M**1** is a voltage value such that the larger the current value flowing through the primary coil L**1**, the larger the voltage value is. Therefore, similar to the first embodiment, current flowing through the secondary coil L**2** in the reception apparatus **280** can be prevented from decreasing.

[0056] The immittance circuit **282** according to the present embodiment differs from the first embodiment in that the coil L**3** and the coil L**5** of the immittance circuit **83** of the first embodiment are not provided. According to the present embodiment, a leakage inductance of the secondary coil L**2** is utilized similar to the coil L**3** and the coil L**5** of the immittance circuit **82** of the first embodiment. In other word, the immittance circuit **282** functions as an immittance circuit with the leakage inductance of the secondary coil L**2**, the coils L**4** and L**6** and the capacitor C**4**.

[0057] The rectifier circuit **283** according to the present embodiment is configured such that two diodes among four diodes in the diode bridge are replaced by two switching elements. Specifically, the rectifier circuit **283** includes diodes D**1** and D**2**, and switching elements Q**1** and Q**2** as a switch. The diodes D**1** and D**2** constitute an upper arm connected to a positive electrode side supply line N**3** connected to the positive electrode of the battery **84**. The switching elements Q**1** and Q**2**

constitute a lower arm connected to a negative electrode side supply line N**4** connected to the negative electrode of the battery **84**. The switching elements Q**1** and Q**2** are complementarily driven. A control signal outputted from the secondary side control circuit **85** is transmitted to each of the gate terminals of the switching elements Q**1** and Q**2**. According to the present embodiment, the switching elements Q**1** and Q**2** are each configured of MOSFET. According to the present embodiment, as a protection switch, a triac TR. A signal outputted from the secondary side control circuit **85** is transmitted to the gate terminal of the triac TR.
[0058] As shown in FIG. **5**, when determining that the stop signal is received at step S**5** and determining that an abnormality signal is received at step S**7**, the secondary side control circuit **85** sets, at step S**11**, the switching elements Q**1** and Q**2** of the rectifier circuit **283** to be in the conductive state. Thus, since the first feeding line N**1** and the second feeding line N**2** are short-circuited via the switching elements Q**1** and Q**2**, the current supplied to the battery **84** can be lowered. Hence, the battery **84** can be prevented from being applied with an excessive current and an excessive voltage, thereby protecting the battery **84**. Since the immittance circuit **282** serves as a constant current source when viewing from the output side, even in the case where the switching elements Q**1** and Q**2** are set to be in the conductive state to cause a short-circuit between two output nodes of the immittance circuit **282**, unlike a constant voltage source, an excessive current can be prevented from flowing. Accordingly, the battery **84** can be protected while preventing the switching elements Q**1** and Q**2** from being applied with excessive current and voltage.
[0059] The secondary side control circuit **85** changes, at step S**15**, the state of the triac TR as a protection switch to be in the conductive state. Thus, similar to the first embodiment, current flowing through the secondary coil L**2** can be reduced. The states of the switching elements Q**1** and Q**2** are set to be in the conductive state before changing the state of the triac TR to be in the conductive state, whereby the battery **84** can be protected earlier.
[0060] The primary side control circuit **13** outputs, at step S**19**, a high level signal for setting the switch SW**21** to be in a conductive state, when determining, at step S**17**, that the voltage value V d indicated by the signal outputted from the voltage sensor M**1** is lower than the reference voltage Vth. Thus, the primary side resonant circuit **212** is in a non-resonant state at the operating frequency and the power transmission is stopped.
[0061] According to the above-described second embodiment, advantageous effects same as those in the first embodiment can be obtained. Moreover, while the protection switch SW**1** is being changed to be in a conductive state, the switching elements Q**1** and Q**2** of the rectifier circuit are set to be in the conductive state, whereby the battery **84** can be protected earlier.
C. Third Embodiment
[0062] As shown in FIG. **6**, the contactless power supply system **301** according to the present embodiment differs from the above-described embodiments in that the configuration of the primary resonant circuit **312** of the transmission apparatus **310**, the circuit configuration of the reception apparatus **380**, the configuration of the protection switch and the power supply sequence are different. For configurations and process steps same as those in the first embodiment, the same reference symbols are applied and detailed explanation will be omitted.
[0063] The primary resonant circuit **312** according to the present embodiment is configured such that a primary capacitor C**31** is connected in parallel to a primary coil L**1**. The transmission apparatus **310** according to the present embodiment further includes a resistor R**1**. The resistor R**1** is connected in series to the primary coil L**1**.
[0064] According to the present embodiment, the voltage sensor M**1** as the primary detection circuit detects the voltage across the resistor R**1** and outputs the signal indicating the detection value to the primary side control circuit **13**. The detection value of the voltage sensor M**1** changes such that the larger the current value of the current flowing through the primary coil L**1**, the larger the detection value is. Hence, similar to the first embodiment, current flowing through the secondary coil L**2** in the reception apparatus **280** can be prevented from decreasing. The

transmission apparatus **310** may include a coil instead of the resistor R**1**. In this case, the voltage sensor M**1** detects voltage across the coil.

[0065] According to the present embodiment, the switch SW**31** as the variable impedance element is connected in series to the primary coil L**1**. In the case where the switch **31** is in a non-conductive state, the impedance of the switch **31** becomes higher, causing a non-resonant state of the primary resonant circuit **312**.

[0066] The reception apparatus **380** includes a semiconductor relay RE as a protection switch. According to the present embodiment, the semiconductor relay RE bypasses the secondary capacitor C**3**. The semiconductor relay RE may be connected to bypass the secondary capacitor C**2** not the secondary capacitor C**3**.

[0067] As shown in FIG. **7**, when determining that the stop signal is received at step S**5**, or determining that an abnormality signal is received at step S**7**, the secondary side control circuit **85** sets, at step S**13**, the switching elements Q**1** and Q**2** of the rectifier circuit **283** to be in a non-conductive state. The secondary side control circuit **85** changes the state of the semiconductor relay RE to be in a conductive state at step S**15**. Since the semiconductor relay RE is connected in parallel to the secondary capacitor C**3**, assuming that the semiconductor relay RE changes the state to be in the conductive state during the switching elements Q**1** and Q**2** of the rectifier circuit **28** being in the conductive state, excessive current possibly flows through the secondary coil L**2**. In this respect, the semiconductor relay RE is changed to be in the conductive state during the switching elements Q**1** and Q**2** being in the non-conductive state. Hence, the secondary coil L**2** can be prevented from being damaged.

[0068] According to the above-described third embodiment, advantageous effects same as those in the above-described embodiments can be obtained. Moreover, the semiconductor relay RE is changed to be in the conductive state during the switching elements Q**1** and Q**2** being in the non-conductive state, whereby the secondary coil L**2** can be prevented from being damaged.

D. Fourth Embodiment

[0069] As shown in FIG. **8**, the contactless power supply system **401** according to the present embodiment differs from the above-described respective embodiments in that the circuit configuration of the transmission apparatus **410** and the circuit configuration of the reception apparatus **480** are different. For configurations and process steps same as those in the first embodiment, the same reference symbols are applied and detailed explanation will be omitted.

[0070] The transmission apparatus **410** includes a characteristics changing circuit **15**. The characteristics changing circuit **15** is a closed circuit in which the coil L**41** and the capacitor C**42** are connected in series. The coil L**41** is disposed in a location capable of being magnetically coupled with the primary coil L**1**. The resonant frequency of the characteristics changing circuit **15** is higher than the operating frequency.

[0071] The characteristics changing circuit **15** has a function of causing a current flowing through the primary coil L**1** to be smaller in the case where a distance between the primary coil L**1** and the secondary coil L**2** is long and a coupling coefficient between the primary coil L**1** and the secondary coil L**2** is small. In more detail, the capacitance of the primary capacitor C**1** is set to be a value with which a resonant state is produced at the operating frequency, in the case where a target value of the coupling coefficient between the primary coil L**1** and the second coil L**2** is satisfied. The target value of the coupling coefficient refers to a coupling coefficient value in the case where the distance between the primary coil L**1** and the secondary coil L**2** is short enough (i.e. target distance) to perform a contactless power supply operation. In the case where the coupling coefficient between the primary coil L**1** and the secondary coil L**2** is small, the inductance of the primary resonant circuit **12** is large and the current flowing through the primary coil L**1** becomes small.

[0072] The reception apparatus **480** includes two protection switches SW**41** and SW**42**. The protection switches SW**41** and SW**42** are semiconductor switches. According to the present

embodiment, the protection switches **41** and **42** are integrated into a single MOSFET. The protection switch SW**41** is inserted into the first feeding line N**1**. The protection switch SW**42** is inserted into the second feeding line N**2**.
[0073] As other embodiments of the protection switches SW**41** and SW**42**, a bi-directional switch having two MOSFETs may be utilized. Also, an embodiment may be employed in which the protection switch is inserted into only either the first feeding line N**1** or the second feeding line N**2**.
[0074] The rectifier circuit **483** includes two diodes that constitute the lower arm, and two switching elements Q**1** and Q**2**.
[0075] Similar to the first embodiment, when determining that the stop signal is received, or an abnormality signal is received, the secondary side control circuit **85** changes the state of the protection switches SW**1** and SW**2** to be non-conductive state from the conductive state. Thus, since the power supply to the battery **84** is cutoff, the battery **84** can be protected.
[0076] When setting the protection switches SW**41** and SW**42** to be in the non-conductive state, the secondary resonant circuit **81** is in the non-resonant state, and the current flowing through the secondary coil L**2** decreases. In this case, when viewing from the primary resonant circuit **12** side, it can be presumed that the secondary coil L**2** is not present. Hence, the current I.sub.1 flowing through the primary resonant circuit **12** is expressed by an equation (2).
[00002] $I_1 = r_3 / ({}^{2} \text{ .Math. } L_{13}^{3}) \text{ .Math. } V_1 \quad (2)$
In the equation (2), r.sub.3 is winding resistance of the coil **41**, L**13** is a mutual inductance between the primary coil L**1** and the coil L**41**, V.sub.1 is an output voltage of the AC power source **11**. In the equation (2), since the denominator 'ω.sup.2.Math.L.sub.13.sup.3' is sufficiently larger than the numerator 'r.sub.3', the current I.sub.1 is substantially 0 ampere.
[0077] According to the fourth embodiment as described above, advantageous effects same as those in the above-described embodiments can be obtained.
E. Fifth Embodiment
[0078] As shown in FIG. **9**, a contactless power supply system **501** according to the present embodiment differs from the above-described second embodiment in that the reception apparatus **580** is provided with a state detection circuit **87**. For configurations and process steps same as those in the first embodiment, the same reference symbols are applied and detailed explanation will be omitted.
[0079] The state detection circuit **87** detects whether the state of the transmission apparatus **210** is in a standby state or a transmission state. The state detection circuit **87** includes a temperature sensor M**4**. The temperature sensor M**4** is disposed in the vicinity of the immittance circuit **282**. Note that, the temperature sensor M**4** may not be disposed in the vicinity of the immittance circuit **282** but may be disposed in the vicinity of the switching elements Q**1** and Q**2**, and may detect the temperature in the vicinity of the switching element Q**1** and Q**2**.
[0080] The state detection circuit **87** detects a temperature of the immittance circuit **282** and outputs a signal indicating that the transmission apparatus **210** is in a transmission state to the secondary side control circuit **85**, when the detected temperature Td is higher than a predetermined reference temperature Tth.
[0081] As shown in FIG. **10**, the secondary side control circuit **85** sets, at step S**11** as a first process, the switching elements Q**1** and Q**2** of the rectifier circuit **283** to be in the conductive state. Then, when determining that the detected temperature Td of the temperature sensor M**4** is higher than the reference temperature Tth at step S**14**, the secondary side control circuit **85** changes the state of the triac TR as the protection switch to be in the conductive state at step S**15**.
[0082] At step S**11**, in the case where the switching elements Q**1** and Q**2** of the rectifier circuit **283** are set to be in the conductive state, as described above, the current flowing through the secondary coil L**2** decreases. However, when the circuit constant of the primary resonant circuit **212** is deviated from the design value, with the current flowing through the primary coil L**1**, the detection

value of the voltage sensor M**1** may not be lower than the reference voltage. In this case, the transmission apparatus **210** does not move to the standby state, and since the current similar to that of the reception state flows through the primary coil L**1**, the temperature of the immittance circuit **282** does not decrease. In this respect, the secondary side control circuit **85** changes, when determining that the temperature Td of the temperature sensor M**4** is higher than the reference temperature Tth at step S**14**, the triac Tr to be in the conductive state. Thus, in the case where the transmission apparatus **210** does not move to the standby state even when the switching elements Q**1** and Q**2** of the rectifier circuit **283** are set to be in the conductive state, the triac TR is changed to be in the conductive state, whereby the transmission apparatus **210** can be moved to the standby state. When determining that the detection temperature Td of the temperature sensor M**4** is not higher than the reference temperature Tth, since the transmission apparatus **210** is already moved to the standby state after setting the switching elements Q**1** and Q**2** of the rectifier circuit **283** to be in the conductive state, the secondary side control circuit **85** does not change the protection switch SW**1** to be in the conductive state.

[0083] According to the above-described fifth embodiment, advantageous effects the same as those in the above-described embodiments can be obtained. Further, in the case where the temperature detected by the temperature sensor M**4** is higher than the reference temperature Tth and the power-supply current continues to flow through the secondary coil L**2**, the triac TR is changed to be in the non-conductive state at step S**15**, thereby causing the transmission apparatus **210** to be in the standby state.

F. Other Embodiments

[0084] (F1) According to the above-descried first embodiment, so-called S-S type circuit configuration is employed in which the primary capacitor C**1** is connected in series to the primary coil L**1** in the primary resonant circuit **12**, and the secondary capacitor C**2** is connected in series to the secondary coil L**2** in the secondary resonant circuit **81**. However, the circuit configuration of the primary resonant circuit **12** and the circuit configuration of the secondary resonant circuit **81** are not limited to the S-S type circuit configuration.

[0085] (a) For example, P—S type circuit configuration may be employed in which the primary capacitor C**1** is connected in parallel to the primary coil L**1** in the primary resonant circuit **12**, and the secondary capacitor C**2** is connected in series to the secondary coil L**2** in the secondary resonant circuit **81**.

[0086] (b) Also, P-SS type circuit configuration may be employed in which a capacitor connected in parallel to the primary coil L**1** is provided in addition to the primary capacitor C**1** connected in series to the primary coil L**1**, and two secondary capacitors C**2** are each connected in series to each of the both terminals of the secondary coil L**2** in the secondary resonant circuit **81**.

[0087] (c) Further, the primary resonant circuit **12** may include a closed circuit configured of series-connected coil and capacitor. The coil included in the closed circuit is disposed at a location capable of being magnetically coupled with the secondary coil L**2** in the case where the primary coil L**1** and the secondary coil L**2** are magnetically coupled.

[0088] (d) Furthermore, the capacitor of the closed circuit may be connected in parallel to the coil not connected in series to the coil.

[0089] (e) Also, the primary resonant circuit **12** may be provided with a coil connected in series to the primary coil L**1** and a capacitor connected in parallel to the coil. This coil is disposed at a location capable of being magnetically coupled with the secondary coil L**2** in the case where the primary coil L**1** and the secondary coil L**2** are magnetically coupled.

[0090] (F2) According to the above-described second embodiment, the switching elements Q**1** and Q**2** included in the rectifier circuit **83** are embodied by MOSFETs. As other embodiment, the switching elements Q**1** and Q**2** may be embodied by other semiconductor elements such as IGBTs (i.e. insulated gate bipolar transistors) to which reflux diodes are connected.

[0091] (F3) According to the above-described second embodiment, for the rectifier circuit **283**, the

lower arm is configured of switching elements Q**1** and Q**2**, and the upper arm is configured of a diode. As other embodiment, the rectifier circuit **283** may be embodied by a synchronous rectifier circuit in which both of the upper arm and the lower arm are configured of switching elements. In this case, the synchronous rectifier circuit is used to apply AC power to the secondary coil L**2** from the battery **84**. In this respect, at step S**1**, AC power may be applied to the secondary coil L**2**, whereby the secondary coil L**2** functions as a coil for producing magnetic flux.
[0092] (F4) According to the above-described fifth embodiment, the state detection circuit **87** detects the temperature of the immittance circuit **282** and outputs a signal indicating that the transmission apparatus **210** is in the transmission state to the secondary side control circuit **85** in the case where the detected temperature Td is higher than the predetermined reference temperature Tth. As other embodiment of the state detection circuit **87**, the detection temperature Td detected by the temperature sensor M**4** at step S**11** may be stored as the reference temperature, and may output a signal indicating that the transmission apparatus **210** is in the transmission state to the secondary side control circuit **85** in the case where a difference between the reference temperature and the current detected temperature is within a predetermined reference range.
[0093] (F5) According to the above-described fifth embodiment, the state detection circuit **87** detects the temperature of the immittance circuit **282** to detect the state of the transmission apparatus **210**. As other embodiment, a sensor that detects current flowing through the secondary coil L**2** or voltage of the secondary coil L**2** may be provided so as to determine that the transmission apparatus **210** is in the transmission state in the case where the current flowing through the secondary coil L**2** or the voltage of the secondary coil L**2** does not decrease.
[0094] The present disclosure is not limited to the above-described embodiments and modifications, and can be realized in various configurations without departing from the spirit of the present disclosure. For example, the technical features in the embodiments and modifications corresponding to the technical features in each form described in the summary of the invention column can be appropriately replaced or combined in order to solve some or all of the above-described issues or to achieve some or all of the above-described advantageous effects. Furthermore, if a technical feature is not described as essential in this specification, it can be appropriately deleted.
[0095] The present disclosure has been described in accordance with the embodiments. However, the present disclosure is not limited to the embodiments and structure thereof. The present disclosure includes various modification examples and modifications within the equivalent configurations. Further, various combinations and modes and other combinations and modes including one element or more or less elements of those various combinations are within the range and technical scope of the present disclosure.
Other Embodiments
The features of the present disclosure will be described as follows.
(Form 1)
A contactless power supply system (**1**, **101-401**) comprising: [0096] a transmission apparatus (**10**, **210-410**); and [0097] a reception apparatus (**80**, **280-480**) to which the transmission apparatus supplies power in a contactless manner,
wherein [0098] the transmission apparatus comprises: [0099] a primary resonant circuit (**12**, **212**, **312**) including a primary coil (L**1**) and a primary capacitor (C**1**); [0100] an AC power source (**11**) that supplies AC power having a predetermined operating frequency to the primary resonant circuit; [0101] a variable impedance element (C**1**, SW**21**, SW**31**) connected between the primary coil and the AC power source to change a state of the transmission apparatus between a transmission state and a standby state; [0102] a primary side control circuit (**13**) that changes an impedance of the variable impedance element; and [0103] a primary detection circuit (**14**, M**1**) that detects at least one of a magnitude of a magnetic flux interlinking with the primary coil and a magnitude of a magnetic flux in the vicinity of the primary coil, [0104] the reception apparatus

comprises: [0105] a secondary resonant circuit (**81**) including a secondary coil (L**2**) to be magnetically coupled with the primary coil, and a secondary capacitor (C**2**, C**3**); [0106] a rectifier circuit (**83**, **283**, **483**) that rectifies an AC power outputted from the secondary resonant circuit; [0107] an immittance circuit (**82**, **282**) connected between the rectifier circuit and the secondary resonant circuit; [0108] a load (**83**) to which a DC power outputted from the rectifier circuit is supplied; [0109] a protection switch (SW**1**, TR, RE, SW**41**, SW**42**) of which the state is changed to be in a conductive state or a non-conductive state, thereby causing the secondary resonant circuit to be in a non-resonant state; and [0110] a secondary side control circuit (**85**) that sets the state of the protection switch to be in either the conductive state or the non-conductive state, and [0111] the primary side control circuit is configured to change the impedance of the variable impedance element, using a detection value of the primary detection circuit which changes depending on the state of the protection switch being set to be in the conductive state or the non-conductive state, thereby causing the reception apparatus to be in the standby state from the transmission state.
(Form 2)
The contactless power supply system according to form 1,
wherein [0112] the secondary capacitor is connected in series to the secondary coil; [0113] the protection switch is connected in parallel to the secondary coil; and [0114] the secondary side control circuit is configured to set the protection switch to be in the conductive state in response to a reception of a power supply stop signal.
(Form 3)
The contactless power supply system according to form 2,
wherein [0115] the protection switch is configured as at least one of a bi-directional switch using two MOSFETs, a semiconductor relay, and a triac.
(Form 4)
The contactless power supply system according to form 2 or 3,
wherein [0116] the rectifier circuit includes a rectifier switch (Q**1**, Q**2**) in at least either a lower arm or an upper arm; [0117] the secondary side control circuit is configured to set, in response to a reception of a power supply stop signal, the rectifier switch to be in the conductive state before setting the protection switch to be in the conductive state.
(Form 5)
The contactless power supply system according to form 1,
wherein [0118] the secondary capacitor is connected in series to the secondary coil; [0119] the protection switch is connected in parallel to the secondary capacitor; and the secondary side control circuit sets the protection switch to be in the conductive state in response to a reception of the power supply stop signal.
(Form 6)
The contactless power supply system according to form 5,
wherein [0120] the protection switch is configured as at least one of a bi-directional switch using two MOSFETs, a semiconductor relay, and a triac.
(Form 7)
The contactless power supply system according to form 5 or 6,
wherein [0121] the rectifier circuit includes a rectifier switch (Q**1**, Q**2**) in at least either a lower arm or an upper arm; [0122] the secondary side control circuit is configured to set, in response to a reception of a power supply stop signal, the protection switch to be in the conductive state after setting the rectifier switch to be in the non-conductive state.
(Form 8)
The contactless power supply system according to form 1,
wherein [0123] the secondary capacitor is connected in series to the secondary coil; [0124] the protection switch is a semiconductor switching element and connected in series between the secondary capacitor and the rectifier circuit; and [0125] the secondary side control circuit changes,

in response to a reception of a stop power supply signal, a state of the protection switch to be in the non-conductive state.

(Form 9)

The contactless power supply system according to form 8,

wherein [0126] the protection switch is a bi-directional switch using two MOSFETs.

(Form 10)

The contactless power supply system according to form 8,

wherein [0127] the protection switch is configured of a single MOSFET.

(Form 11)

A contactless power supply system (**501**) comprising: [0128] a transmission apparatus (**210**); and [0129] a reception apparatus (**580**) to which the transmission apparatus supplies power in a contactless manner,

wherein [0130] the transmission apparatus comprises: [0131] a primary resonant circuit (**212**) including a primary coil (L**1**) and a primary capacitor (C**1**); [0132] an AC power source (**11**) that supplies AC power having a predetermined operating frequency to the primary resonant circuit; [0133] a variable impedance element (SW**21**) connected between the primary coil and the AC power source to change a state of the transmission apparatus between a transmission state and a standby state; [0134] a primary side control circuit (**13**) that changes an impedance of the variable impedance element; and [0135] a primary detection circuit (M**1**) that detects at least one of a magnitude of a magnetic flux interlinking with the primary coil and a magnitude of a magnetic flux in the vicinity of the primary coil, [0136] the reception apparatus comprises: [0137] a secondary resonant circuit (**81**) including a secondary coil (L**2**) to be magnetically coupled with the primary coil, and a secondary capacitor (C**2**, C**3**); [0138] a rectifier circuit (**283**) that rectifies an AC power outputted from the secondary resonant circuit, including a rectifier switch (Q**1**, Q**2**) in at least either a lower arm or an upper arm; [0139] an immittance circuit (**282**) connected between the rectifier circuit and the secondary resonant circuit; [0140] a load (**84**) to which a DC power outputted from the rectifier circuit is supplied; [0141] a protection switch (TR) of which the state is changed to be in a conductive state or a non-conductive state, thereby causing the secondary resonant circuit to be in a non-resonant state; [0142] a secondary side control circuit (**85**) that sets the state of the protection switch to [0143] be in either the conductive state or the non-conductive state; and [0144] a state detection circuit (**87**) that detects a state of the transmission apparatus,

wherein [0145] the secondary side control circuit performs a first process (S**11**) that sets, in response to a reception of a power supply stop signal, the rectifier switch to be in the conductive state before setting the protection switch to be in the conductive state, and in the case where the state of the transmission apparatus detected by the state detection unit after performing the first process is in the transmission state, the secondary side control circuit sets the protection switch to be in the conductive state; [0146] the primary side control circuit is configured to change the impedance of the variable impedance element, using at least one of a detection value of the primary detection circuit which changes depending on the state of the rectifier switch being set to be in the conductive state and a detection value of the primary detection circuit which changes depending on the state of the protection switch being set to be in the conductive state or the non-conductive state, thereby causing the reception apparatus to be in the standby state from the transmission state.

(Form 12)

The contactless power supply system according to form 11,

wherein [0147] the state detection circuit detects a temperature of at least one of the rectifier switch and the immittance circuit, and outputs a signal indicating that the transmission apparatus is in the transmission state in the case where the detected temperature is higher than a predetermined reference temperature (Tth).

(Form 13)

A transmission apparatus (**10**, **210-410**) that supplies power to a reception apparatus (**80**, **280-480**) in a contactless manner,

wherein [0148] the transmission apparatus comprises: [0149] a primary resonant circuit (**12**, **212**, **312**) including a primary coil (L**1**) and a primary capacitor (C**1**); [0150] an AC power source (**11**) that supplies AC power having a predetermined operating frequency to the primary resonant circuit; [0151] a variable impedance element (C**1**, SW**21**, SW**31**) connected between the primary coil and the AC power source to change a state of the transmission apparatus between a transmission state and a standby state; [0152] a primary side control circuit (**13**) that changes an impedance of the variable impedance element; and [0153] a primary detection circuit (**14**, M**1**) that detects at least one of a magnitude of a magnetic flux interlinking with the primary coil and a magnitude of a magnetic flux in the vicinity of the primary coil, [0154] the reception apparatus comprises: [0155] a secondary resonant circuit (**81**) including a secondary coil (L**2**) to be magnetically coupled with the primary coil, and a secondary capacitor (C**2**, C**3**); [0156] a rectifier circuit (**83**, **283**, **483**) that rectifies an AC power outputted from the secondary resonant circuit; [0157] an immittance circuit (**82**, **282**) connected between the rectifier circuit and the secondary resonant circuit; [0158] a load (**83**) to which a DC power outputted from the rectifier circuit is supplied; [0159] a protection switch (SW**1**, TR, RE, SW**41**, SW**42**) of which the state is changed to be in a conductive state or a non-conductive state, thereby causing the secondary resonant circuit to be in a non-resonant state; [0160] a secondary side control circuit (**85**) that sets the state of the protection switch to be in either the conductive state or the non-conductive state,

wherein [0161] the primary side control circuit is configured to change the impedance of the variable impedance element, using a detection value of the primary detection circuit which changes depending on the state of the protection switch being set to be in the conductive state or the non-conductive state, thereby causing the reception apparatus to be in the standby state from the transmission state.

(Form 14)

[0162] A reception apparatus (**80**, **280-480**) supplied with power from a transmission apparatus (**10**, **210-410**) in a contactless manner,

wherein [0163] the transmission apparatus comprises: [0164] a primary resonant circuit (**12**, **212**, **312**) including a primary coil (L**1**) and a primary capacitor (C**1**); [0165] an AC power source (**11**) that supplies AC power having a predetermined operating frequency to the primary resonant circuit; [0166] a variable impedance element (C**1**, SW**21**, SW**31**) connected between the primary coil and the AC power source to change a state of the transmission apparatus between a transmission state and a standby state; [0167] a primary side control circuit (**13**) that changes an impedance of the variable impedance element; and [0168] a primary detection circuit (**14**, M**1**) that detects at least one of a magnitude of a magnetic flux interlinking with the primary coil and a magnitude of a magnetic flux in the vicinity of the primary coil, [0169] the reception apparatus comprises: [0170] a secondary resonant circuit (**81**) including a secondary coil (L**2**) to be magnetically coupled with the primary coil, and a secondary capacitor (C**2**, C**3**); [0171] a rectifier circuit (**83**, **283**, **483**) that rectifies an AC power outputted from the secondary resonant circuit; [0172] an immittance circuit (**82**, **282**) connected between the rectifier circuit and the secondary resonant circuit; [0173] a load (**83**) to which a DC power outputted from the rectifier circuit is supplied; [0174] a protection switch (SW**1**, TR, RE, SW**41**, SW**42**) of which the state is changed to be in a conductive state or a non-conductive state, thereby causing the secondary resonant circuit to be in a non-resonant state; [0175] a secondary side control circuit (**85**) that sets the state of the protection switch to be in either the conductive state or the non-conductive state,

wherein [0176] the primary side control circuit is configured to change the impedance of the variable impedance element, using a detection value of the primary detection circuit which changes depending on the state of the protection switch being set to be in the conductive state or the non-conductive state, thereby causing the reception apparatus to be in the standby state from the transmission state.

CONCLUSION

[0177] The present disclosure can be embodied in the following manners.

[0178] According to a first aspect of the present disclosure, a contactless power supply system is provided to include a transmission apparatus and a reception apparatus to which the transmission apparatus supplies power in a contactless manner. The transmission apparatus includes: a primary resonant circuit including a primary coil and a primary capacitor; an AC power source that supplies

[0179] AC power having a predetermined operating frequency to the primary resonant circuit; a variable impedance element connected between the primary coil and the AC power source to change a state of the transmission apparatus between a transmission state and a standby state; a primary side control circuit that changes an impedance of the variable impedance element; and a primary detection circuit that detects at least one of a magnitude of a magnetic flux interlinking with the primary coil and a magnitude of a magnetic flux in the vicinity of the primary coil. The reception apparatus includes: a secondary resonant circuit including a secondary coil to be magnetically coupled with the primary coil, and a secondary capacitor; a rectifier circuit that rectifies AC power outputted from the secondary resonant circuit; an immittance circuit connected between the rectifier circuit and the secondary resonant circuit; a load to which a DC power outputted from the rectifier circuit is supplied; a protection switch of which the state is changed to be in a conductive state or a non-conductive state, thereby causing the secondary resonant circuit to be in a non-resonant state; and a secondary side control circuit that sets the state of the protection switch to be in either the conductive state or the non-conductive state. The primary side control circuit is configured to change the impedance of the variable impedance element, using a detection value of the primary detection circuit which changes depending on the state of the protection switch being set to be in the conductive state or the non-conductive state, thereby causing the reception apparatus to be in the standby state from the transmission state.

[0180] According to the first aspect, since the reception apparatus includes a protection switch, when the reception apparatus is in an abnormal state, the protection switch is used to decrease an amount of current supplied to the load, whereby the load can be protected. Further, the primary side control circuit increases the impedance of the primary resonant circuit to be higher in the case where the magnetic flux in the vicinity of the primary coil becomes smaller in the transmission state, thereby causing the state to be in the standby state. Thus, power consumption which does not contribute the power supply in the transmission apparatus can be reduced.

[0181] According to a second aspect of the present disclosure, a contactless power supply system is provided to include a transmission apparatus; and a reception apparatus to which the transmission apparatus supplies power in a contactless manner. The transmission apparatus includes: a primary resonant circuit including a primary coil and a primary capacitor; an AC power source that supplies AC power having a predetermined operating frequency to the primary resonant circuit; a variable impedance element connected between the primary coil and the AC power source to change a state of the transmission apparatus between a transmission state and a standby state; a primary side control circuit that changes an impedance of the variable impedance element; and a primary detection circuit that detects at least one of a magnitude of a magnetic flux interlinking with the primary coil and a magnitude of a magnetic flux in the vicinity of the primary coil. The reception apparatus includes: a secondary resonant circuit including a secondary coil to be magnetically coupled with the primary coil, and a secondary capacitor; a rectifier circuit that rectifies an AC power outputted from the secondary resonant circuit, including a rectifier switch in at least either a lower arm or an upper arm; an immittance circuit connected between the rectifier circuit and the secondary resonant circuit; a load to which a DC power outputted from the rectifier circuit is supplied; a protection switch of which the state is changed to be in a conductive state or a non-conductive state, thereby causing the secondary resonant circuit to be in a non-resonant state; a secondary side control circuit that sets the state of the protection switch to be in either the conductive state or the non-conductive state; and a state detection circuit that detects a state of the

transmission apparatus. The secondary side control circuit performs a first process that sets, in response to a reception of a power supply stop signal, the rectifier switch to be in the conductive state before setting the protection switch to be in the conductive state, and in the case where the state of the transmission apparatus detected by the state detection unit after performing the first process is in the transmission state, the secondary side control circuit sets the protection switch to be in the conductive state; the primary side control circuit is configured to change the impedance of the variable impedance element, using at least one of a detection value of the primary detection circuit which changes depending on the state of the rectifier switch being set to be in the conductive state and a detection value of the primary detection circuit which changes depending on the state of the protection switch being set to be in the conductive state or the non-conductive state, thereby causing the reception apparatus to be in the standby state from the transmission state.
[0182] According to the second aspect, since the reception apparatus includes a protection switch and a rectifier circuit including a rectifier switch, when the reception apparatus is in an abnormal state, the protection switch or the rectifier switch of the rectification circuit is used to decrease an amount of current supplied to the load, whereby the load can be protected. Further, the primary side control circuit increases the impedance of the primary resonant circuit to be higher in the case where the magnetic flux in the vicinity of the primary coil becomes smaller in the transmission state, thereby causing the state to be in the standby state. Thus, power consumption which does not contribute the power supply in the transmission apparatus can be reduced.
[0183] According to a third aspect of the present disclosure, a transmission apparatus that supplies power to a reception apparatus in a contactless manner is provided. The transmission apparatus includes: a primary resonant circuit including a primary coil and a primary capacitor; an AC power source that supplies AC power having a predetermined operating frequency to the primary resonant circuit; a variable impedance element connected between the primary coil and the AC power source to change a state of the transmission apparatus between a transmission state and a standby state; a primary side control circuit that changes an impedance of the variable impedance element; and a primary detection circuit that detects at least one of a magnitude of a magnetic flux interlinking with the primary coil and a magnitude of a magnetic flux in the vicinity of the primary coil. The reception apparatus includes: a secondary resonant circuit including a secondary coil to be magnetically coupled with the primary coil, and a secondary capacitor; a rectifier circuit that rectifies an AC power outputted from the secondary resonant circuit; an immittance circuit connected between the rectifier circuit and the secondary resonant circuit; a load to which a DC power outputted from the rectifier circuit is supplied; a protection switch of which the state is changed to be in a conductive state or a non-conductive state, thereby causing the secondary resonant circuit to be in a non-resonant state; a secondary side control circuit that sets the state of the protection switch to be in either the conductive state or the non-conductive state. The primary side control circuit is configured to change the impedance of the variable impedance element, using a detection value of the primary detection circuit which changes depending on the state of the protection switch being set to be in the conductive state or the non-conductive state, thereby causing the reception apparatus to be in the standby state from the transmission state.
[0184] According to the third aspect, since the reception apparatus includes a protection switch, when the reception apparatus is in an abnormal state, the protection switch is used to decrease an amount of current supplied to the load, whereby the load can be protected. Further, the primary side control circuit increases the impedance of the primary resonant circuit to be higher in the case where the magnetic flux in the vicinity of the primary coil becomes smaller in the transmission state, thereby causing the state to be in the standby state. Thus, power consumption which does not contribute the power supply in the transmission apparatus can be reduced.
[0185] According to a fourth aspect of the present disclosure, a reception apparatus supplied with power from a transmission apparatus in a contactless manner is provided. The transmission apparatus includes: a primary resonant circuit including a primary coil and a primary capacitor; an

AC power source that supplies AC power having a predetermined operating frequency to the primary resonant circuit; a variable impedance element connected between the primary coil and the AC power source to change a state of the transmission apparatus between a transmission state and a standby state; a primary side control circuit that changes an impedance of the variable impedance element; and a primary detection circuit that detects at least one of a magnitude of a magnetic flux interlinking with the primary coil and a magnitude of a magnetic flux in the vicinity of the primary coil. The reception apparatus includes: a secondary resonant circuit including a secondary coil to be magnetically coupled with the primary coil, and a secondary capacitor; a rectifier circuit that rectifies an AC power outputted from the secondary resonant circuit; an immittance circuit connected between the rectifier circuit and the secondary resonant circuit; a load to which a DC power outputted from the rectifier circuit is supplied; a protection switch of which the state is changed to be in a conductive state or a non-conductive state, thereby causing the secondary resonant circuit to be in a non-resonant state; a secondary side control circuit that sets the state of the protection switch to be in either the conductive state or the non-conductive state. The primary side control circuit is configured to change the impedance of the variable impedance element, using a detection value of the primary detection circuit which changes depending on the state of the protection switch being set to be in the conductive state or the non-conductive state, thereby causing the reception apparatus to be in the standby state from the transmission state.
[0186] According to the fourth aspect, since the reception apparatus includes a protection switch, when the reception apparatus is in an abnormal state, the protection switch is used to decrease an amount of current supplied to the load, whereby the load can be protected. Further, the primary side control circuit increases the impedance of the primary resonant circuit to be higher in the case where the magnetic flux in the vicinity of the primary coil becomes smaller in the transmission state, thereby causing the state to be in the standby state. Thus, power consumption which does not contribute the power supply in the transmission apparatus can be reduced.

Claims

1. A contactless power supply system comprising: a transmission apparatus; and a reception apparatus to which the transmission apparatus supplies power in a contactless manner, wherein the transmission apparatus comprises: a primary resonant circuit including a primary coil and a primary capacitor; an AC power source that supplies AC power having a predetermined operating frequency to the primary resonant circuit; a variable impedance element connected between the primary coil and the AC power source to change a state of the transmission apparatus between a transmission state and a standby state; a primary side control circuit that changes an impedance of the variable impedance element; and a primary detection circuit that detects at least one of a magnitude of a magnetic flux interlinking with the primary coil and a magnitude of a magnetic flux in the vicinity of the primary coil, the reception apparatus comprises: a secondary resonant circuit including a secondary coil to be magnetically coupled with the primary coil, and a secondary capacitor; a rectifier circuit that rectifies an AC power outputted from the secondary resonant circuit; an immittance circuit connected between the rectifier circuit and the secondary resonant circuit; a load to which a DC power outputted from the rectifier circuit is supplied; and a protection switch of which the state is changed to be in a conductive state or a non-conductive state, thereby causing the secondary resonant circuit to be in a non-resonant state; and a secondary side control circuit that sets the state of the protection switch to be in either the conductive state or the non-conductive state, and the primary side control circuit is configured to change the impedance of the variable impedance element, using a detection value of the primary detection circuit which changes depending on the state of the protection switch being set to be in the conductive state or the non-conductive state, thereby causing the reception apparatus to be in the standby state from the transmission state.

2. The contactless power supply system according to claim 1, wherein the secondary capacitor is connected in series to the secondary coil; the protection switch is connected in parallel to the secondary coil; and the secondary side control circuit is configured to set the protection switch to be in the conductive state in response to a reception of a power supply stop signal.
3. The contactless power supply system according to claim 2, wherein the protection switch is configured as at least one of a bi-directional switch using two MOSFETs, a semiconductor relay, and a triac.
4. The contactless power supply system according to claim 2, wherein the rectifier circuit includes a rectifier switch in at least either a lower arm or an upper arm; the secondary side control circuit is configured to set, in response to a reception of a power supply stop signal, the rectifier switch to be in the conductive state before setting the protection switch to be in the conductive state.
5. The contactless power supply system according to claim 1, wherein the secondary capacitor is connected in series to the secondary coil; the protection switch is connected in parallel to the secondary capacitor; and the secondary side control circuit sets the protection switch to be in the conductive state in response to a reception of the power supply stop signal.
6. The contactless power supply system according to claim 1, wherein the protection switch is configured as at least one of a bi-directional switch using two MOSFETs, a semiconductor relay, and a triac.
7. The contactless power supply system according to claim 5, wherein the rectifier circuit includes a rectifier switch in at least either a lower arm or an upper arm; the secondary side control circuit is configured to set, in response to a reception of a power supply stop signal, the protection switch to be in the conductive state after setting the rectifier switch to be in the non-conductive state.
8. The contactless power supply system according to claim 1, wherein the secondary capacitor is connected in series to the secondary coil; the protection switch is a semiconductor switching element and connected in series between the secondary capacitor and the rectifier circuit; and the secondary side control circuit changes, in response to a reception of a stop power supply signal, a state of the protection switch to be in the non-conductive state.
9. The contactless power supply system according to claim 8, wherein the protection switch is a bi-directional switch using two MOSFETs.
10. The contactless power supply system according to claim 8, wherein the protection switch is configured of a single MOSFET.
11. A contactless power supply system comprising: a transmission apparatus; and a reception apparatus to which the transmission apparatus supplies power in a contactless manner, wherein the transmission apparatus comprises: a primary resonant circuit including a primary coil and a primary capacitor; an AC power source that supplies AC power having a predetermined operating frequency to the primary resonant circuit; a variable impedance element connected between the primary coil and the AC power source to change a state of the transmission apparatus between a transmission state and a standby state; a primary side control circuit that changes an impedance of the variable impedance element; and a primary detection circuit that detects at least one of a magnitude of a magnetic flux interlinking with the primary coil and a magnitude of a magnetic flux in the vicinity of the primary coil, the reception apparatus comprises: a secondary resonant circuit including a secondary coil to be magnetically coupled with the primary coil, and a secondary capacitor; a rectifier circuit that rectifies an AC power outputted from the secondary resonant circuit, including a rectifier switch in at least either a lower arm or an upper arm; an immittance circuit connected between the rectifier circuit and the secondary resonant circuit; a load to which a DC power outputted from the rectifier circuit is supplied; a protection switch of which the state is changed to be in a conductive state or a non-conductive state, thereby causing the secondary resonant circuit to be in a non-resonant state; a secondary side control circuit that sets the state of the protection switch to be in either the conductive state or the non-conductive state; and a state detection circuit that detects a state of the transmission apparatus, wherein the secondary side

control circuit performs a first process that sets, in response to a reception of a power supply stop signal, the rectifier switch to be in the conductive state before setting the protection switch to be in the conductive state, and in the case where the state of the transmission apparatus detected by the state detection unit after performing the first process is in the transmission state, the secondary side control circuit sets the protection switch to be in the conductive state; the primary side control circuit is configured to change the impedance of the variable impedance element, using at least one of a detection value of the primary detection circuit which changes depending on the state of the rectifier switch being set to be in the conductive state and a detection value of the primary detection circuit which changes depending on the state of the protection switch being set to be in the conductive state or the non-conductive state, thereby causing the reception apparatus to be in the standby state from the transmission state.

12. The contactless power supply system according to claim 11, wherein the state detection circuit detects a temperature of at least one of the rectifier switch and the immittance circuit, and outputs a signal indicating that the transmission apparatus is in the transmission state in the case where the detected temperature is higher than a predetermined reference temperature.

13. A transmission apparatus that supplies power to a reception apparatus in a contactless manner, wherein the transmission apparatus comprises: a primary resonant circuit including a primary coil and a primary capacitor; an AC power source that supplies AC power having a predetermined operating frequency to the primary resonant circuit; a variable impedance element connected between the primary coil and the AC power source to change a state of the transmission apparatus between a transmission state and a standby state; a primary side control circuit that changes an impedance of the variable impedance element; and a primary detection circuit that detects at least one of a magnitude of a magnetic flux interlinking with the primary coil and a magnitude of a magnetic flux in the vicinity of the primary coil, the reception apparatus comprises: a secondary resonant circuit including a secondary coil to be magnetically coupled with the primary coil, and a secondary capacitor; a rectifier circuit that rectifies an AC power outputted from the secondary resonant circuit; an immittance circuit connected between the rectifier circuit and the secondary resonant circuit; a load to which a DC power outputted from the rectifier circuit is supplied; a protection switch of which the state is changed to be in a conductive state or a non-conductive state, thereby causing the secondary resonant circuit to be in a non-resonant state; a secondary side control circuit that sets the state of the protection switch to be in either the conductive state or the non-conductive state, wherein the primary side control circuit is configured to change the impedance of the variable impedance element, using a detection value of the primary detection circuit which changes depending on the state of the protection switch being set to be in the conductive state or the non-conductive state, thereby causing the reception apparatus to be in the standby state from the transmission state.

14. A reception apparatus supplied with power from a transmission apparatus in a contactless manner, wherein the transmission apparatus comprises: a primary resonant circuit including a primary coil and a primary capacitor; an AC power source that supplies AC power having a predetermined operating frequency to the primary resonant circuit; a variable impedance element connected between the primary coil and the AC power source to change a state of the transmission apparatus between a transmission state and a standby state; a primary side control circuit that changes an impedance of the variable impedance element; and a primary detection circuit that detects at least one of a magnitude of a magnetic flux interlinking with the primary coil and a magnitude of a magnetic flux in the vicinity of the primary coil, the reception apparatus comprises: a secondary resonant circuit including a secondary coil to be magnetically coupled with the primary coil, and a secondary capacitor; a rectifier circuit that rectifies an AC power outputted from the secondary resonant circuit; an immittance circuit connected between the rectifier circuit and the secondary resonant circuit; a load to which a DC power outputted from the rectifier circuit is supplied; a protection switch of which the state is changed to be in a conductive state or a non-conductive state, thereby causing the secondary resonant circuit to be in a non-resonant state; a secondary side control circuit that sets the state of the protection switch to be in either the conductive state or the non-conductive state, wherein the primary side control circuit is configured to change the impedance of the variable impedance element, using a detection value of the primary detection circuit which changes depending on the state of the protection switch being set to be in the conductive state or the non-conductive state, thereby causing the reception apparatus to be in the standby state from the transmission state.