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POWER RECEPTION APPARATUS****Publication Classification**

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038237, filed on Oct. 24, 2023.(30) **Foreign Application Priority Data**

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(57) **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.

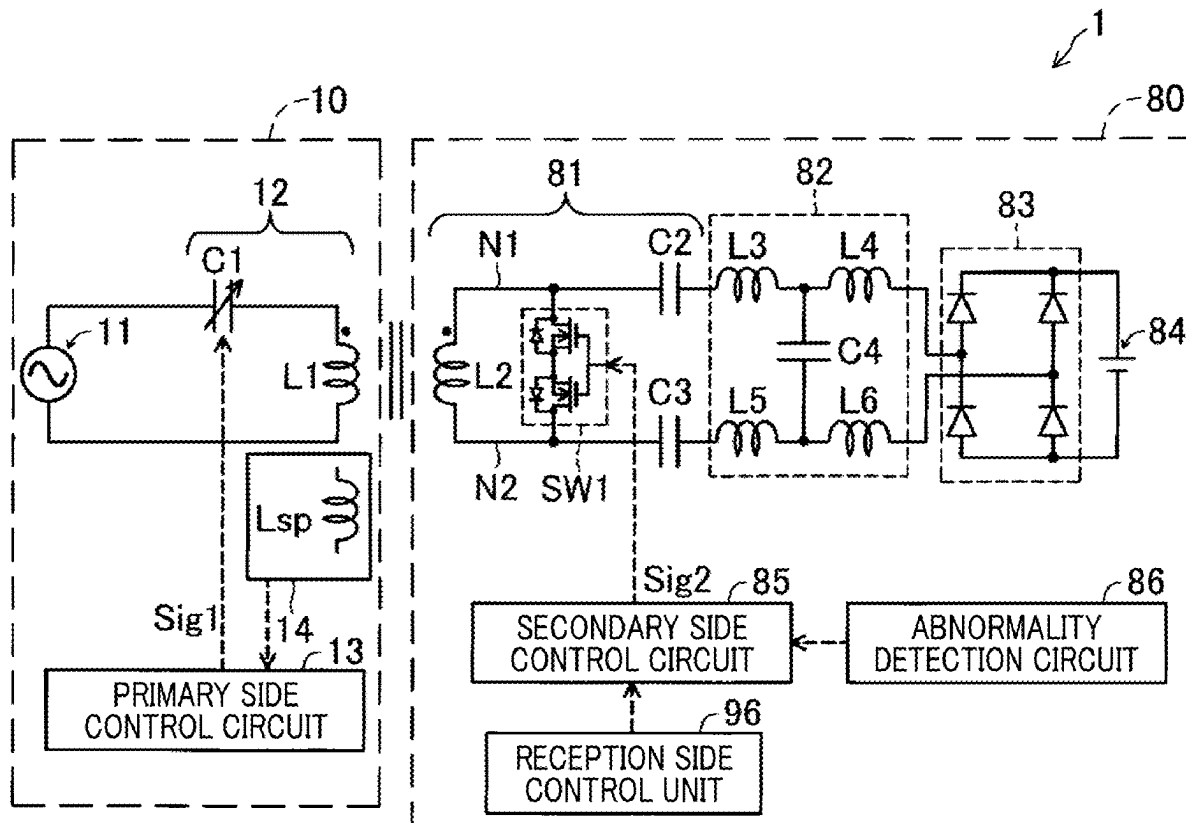


FIG.1

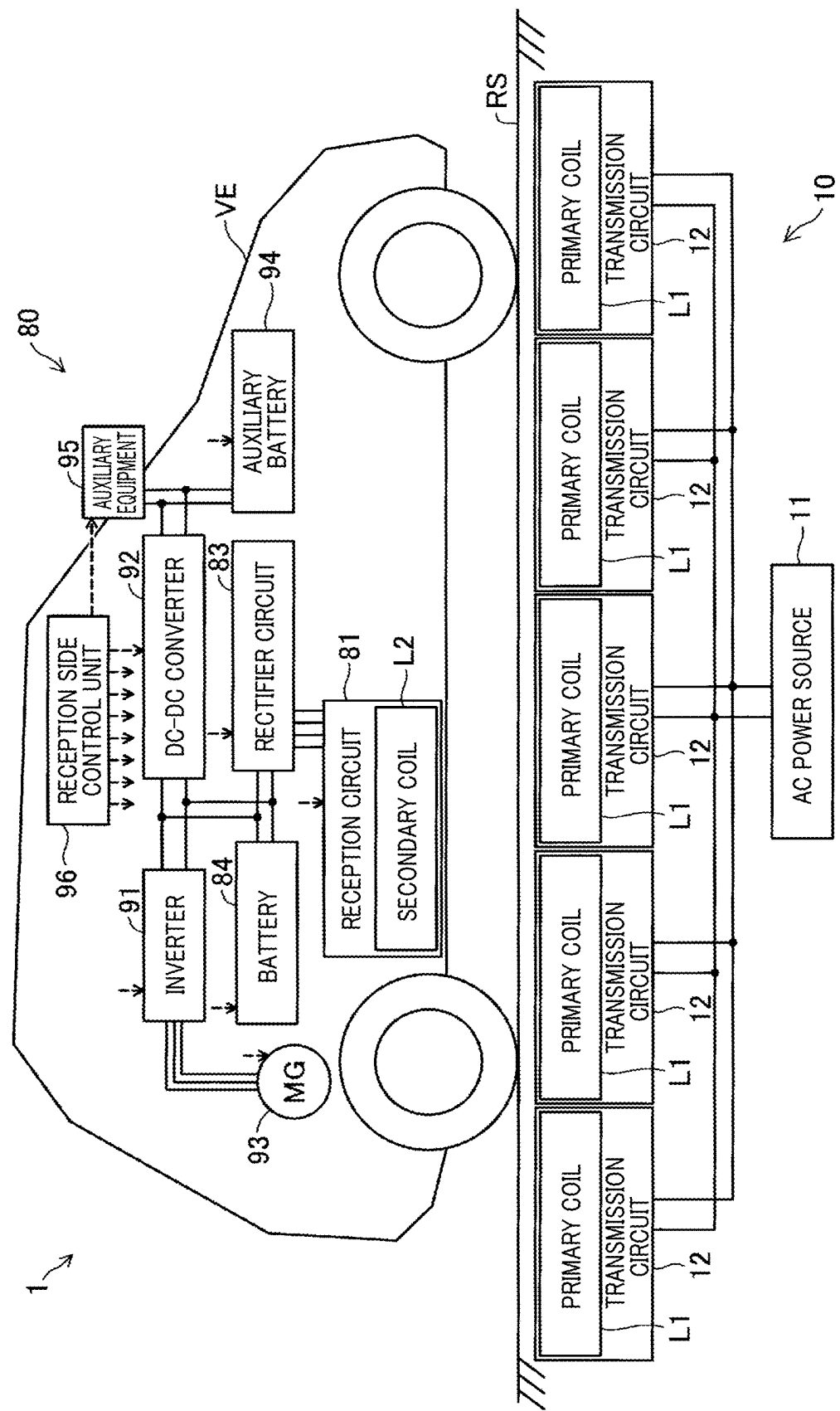


FIG.2

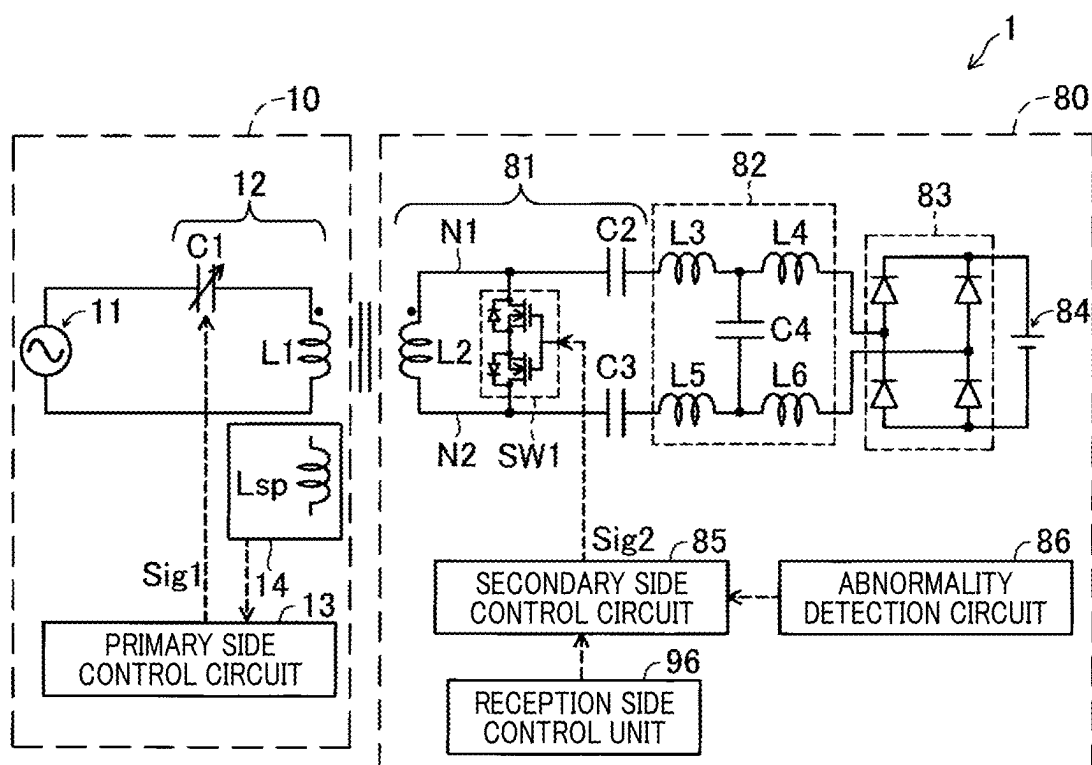


FIG.3

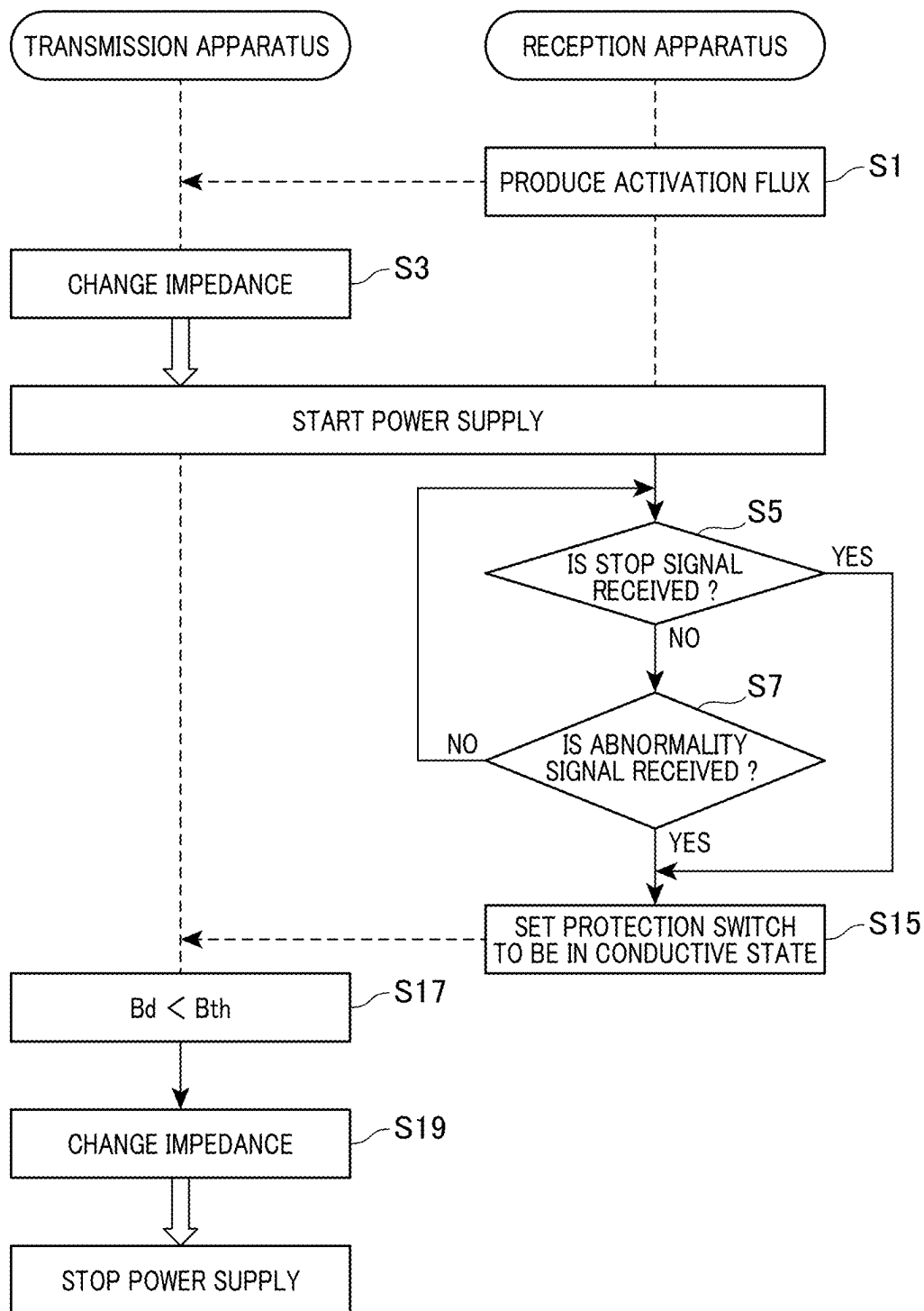


FIG. 4

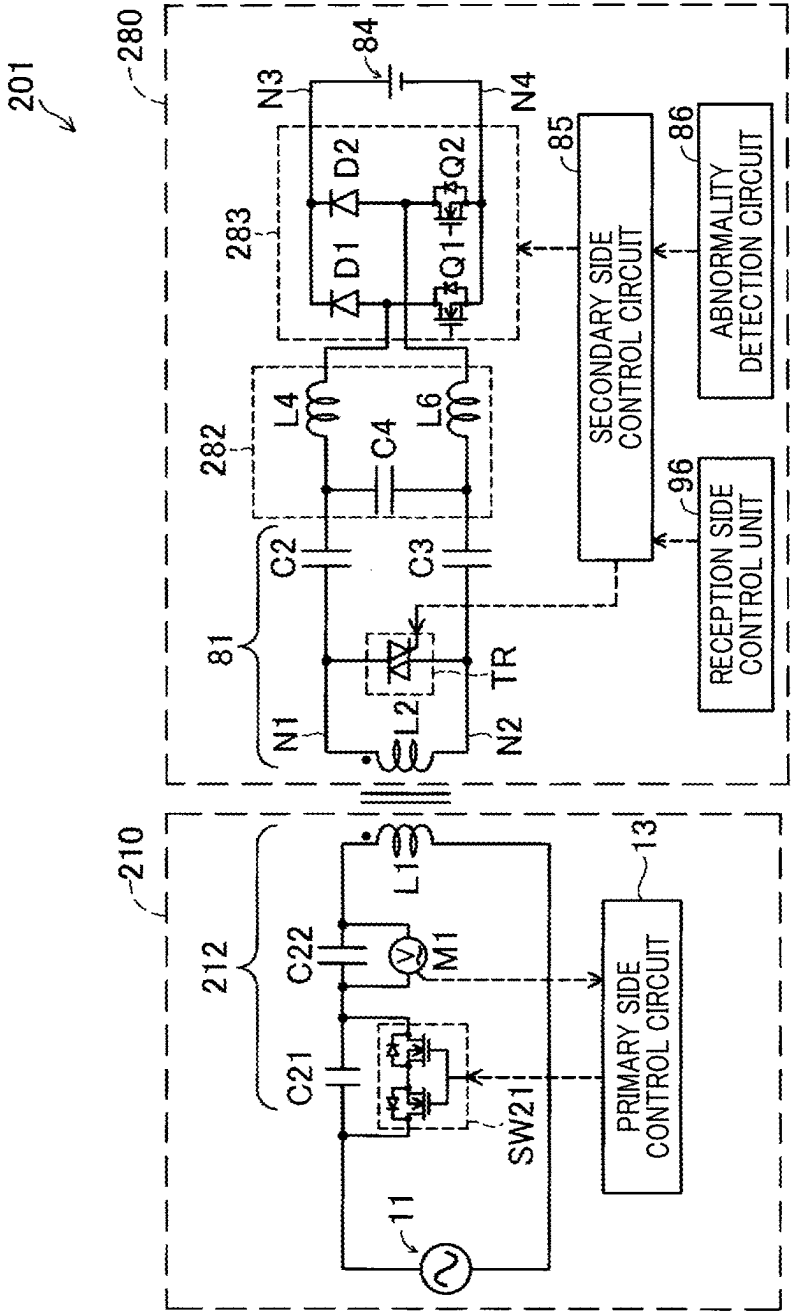


FIG. 5

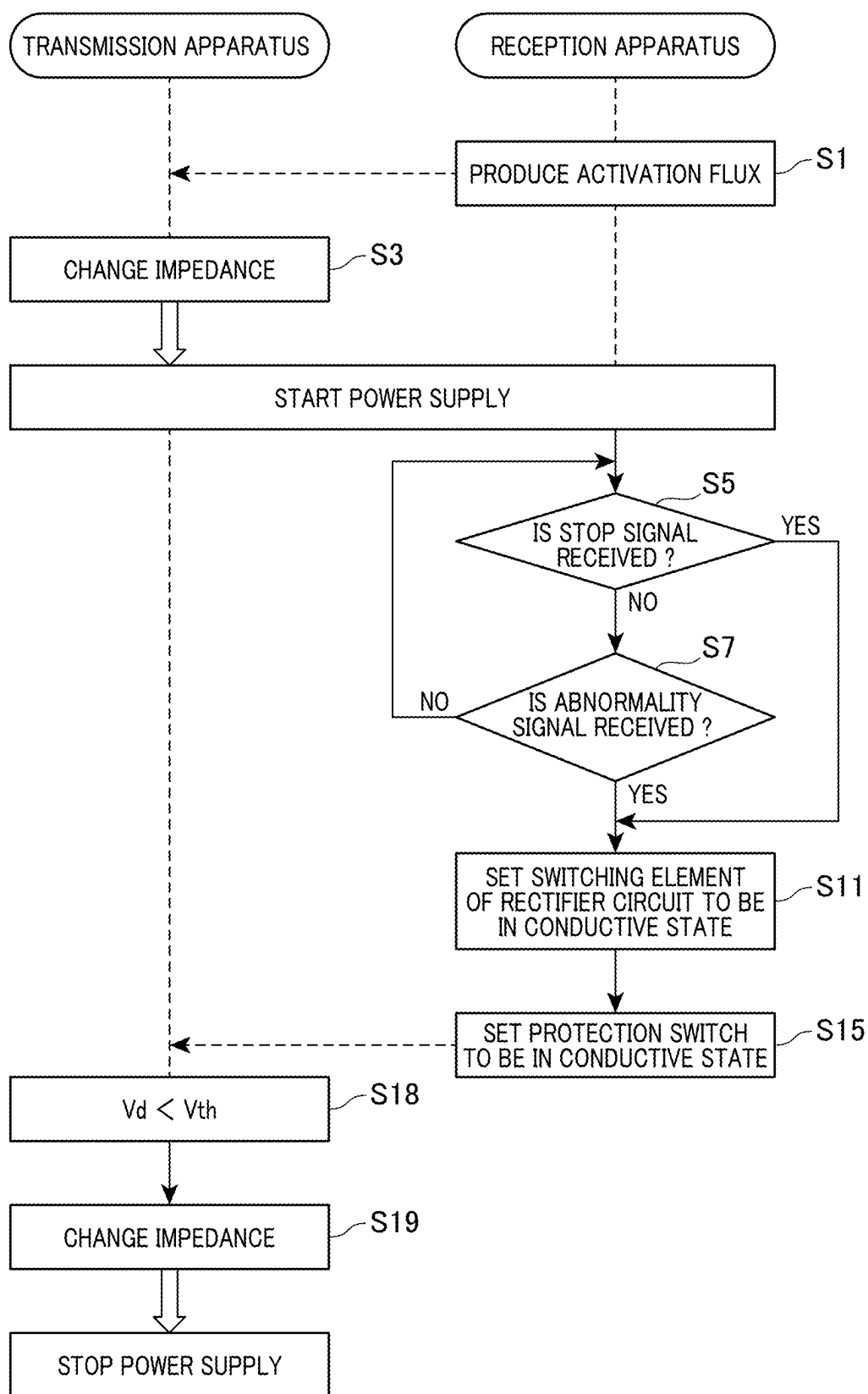


FIG. 6

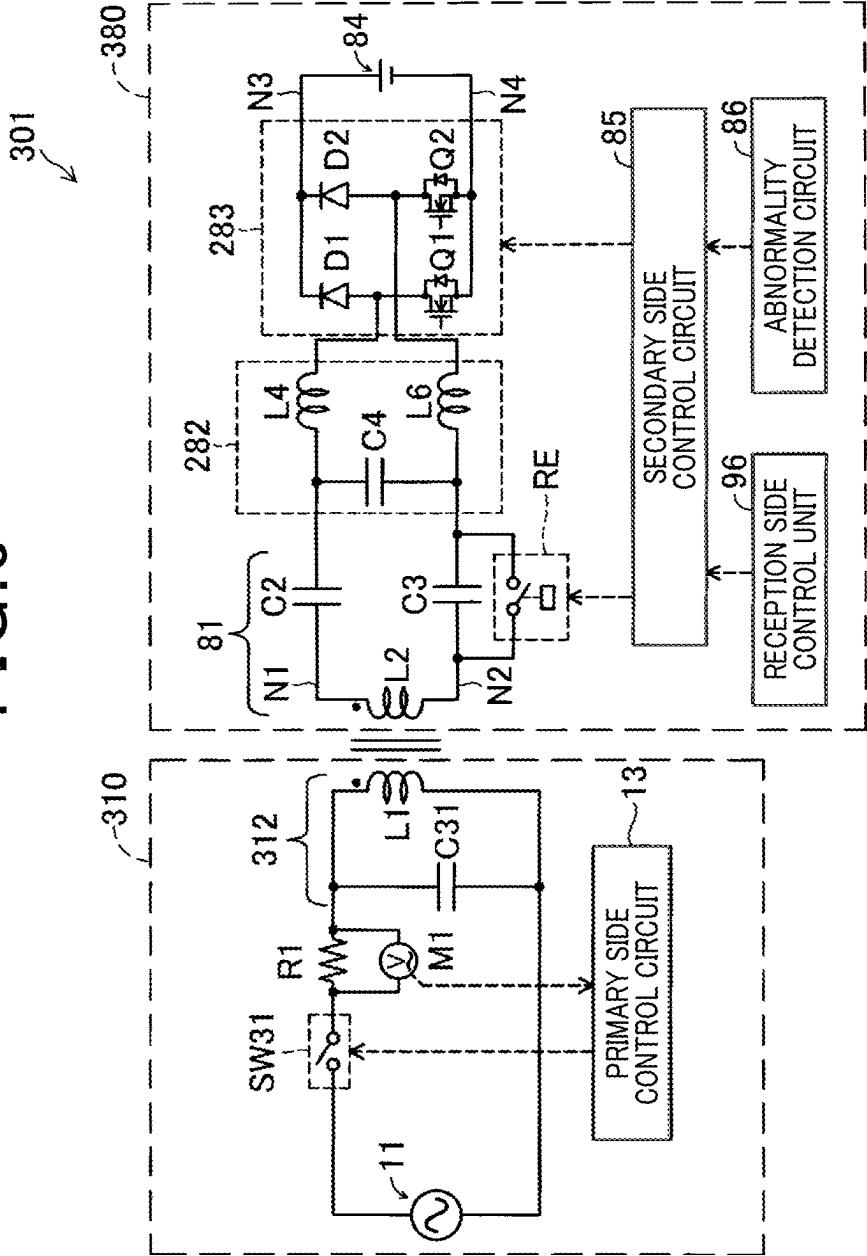


FIG. 7

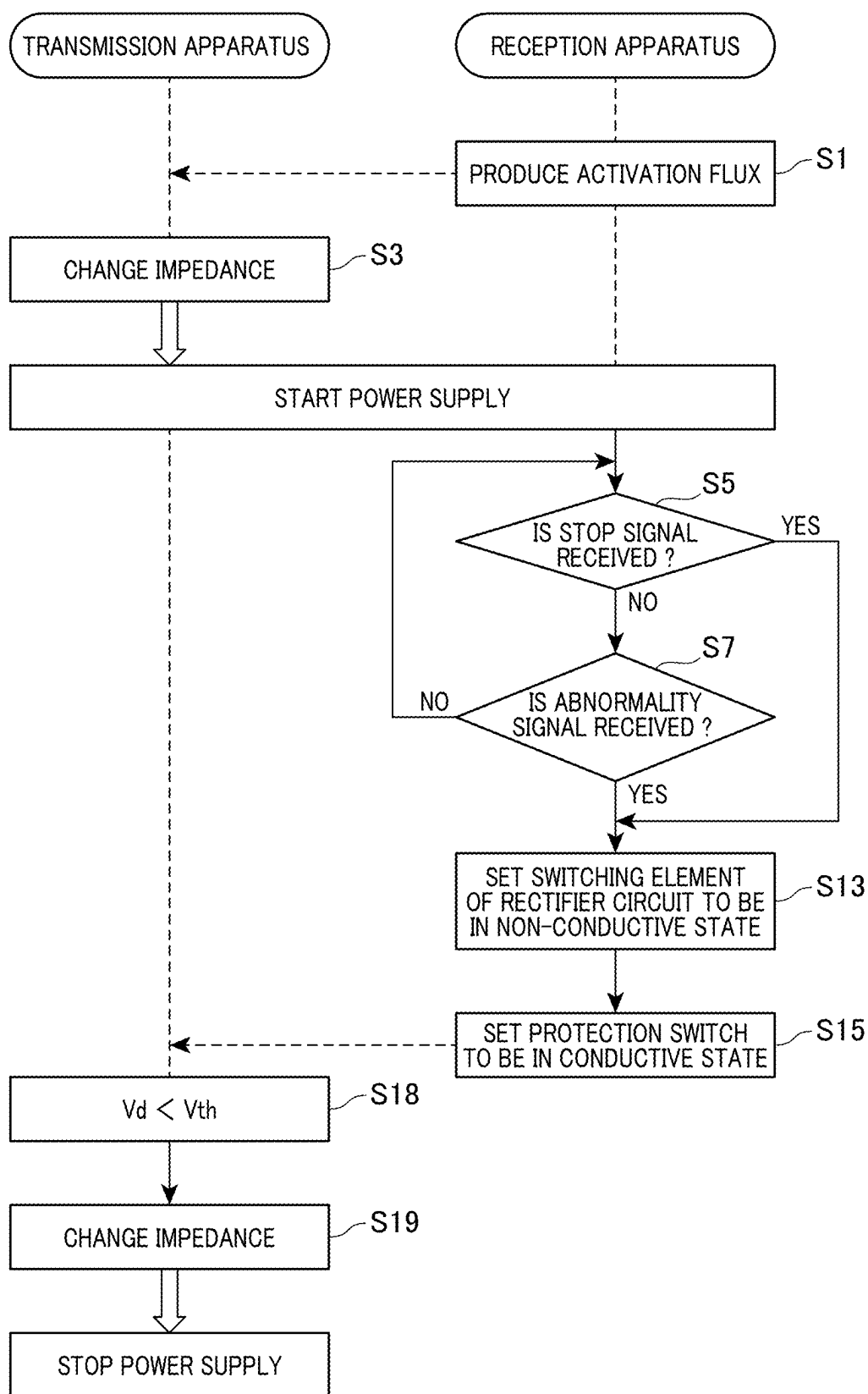


FIG. 8

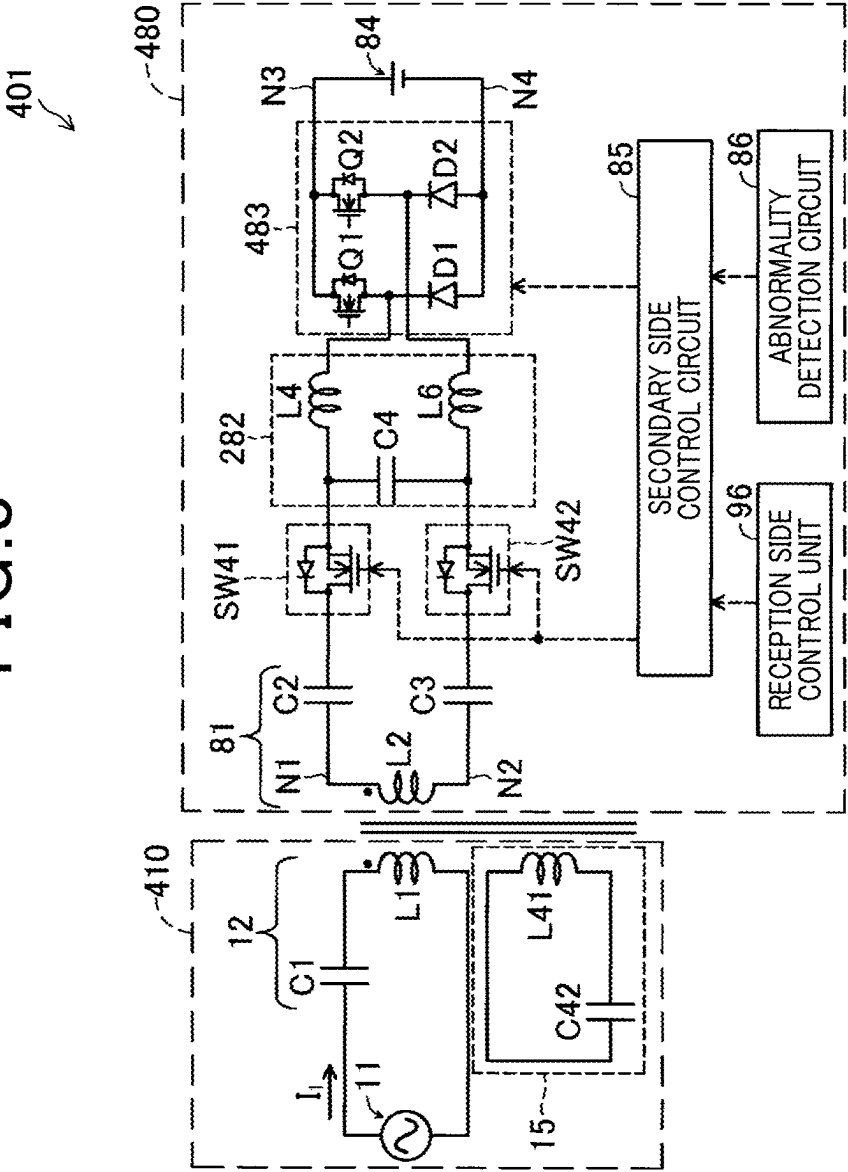


FIG. 9

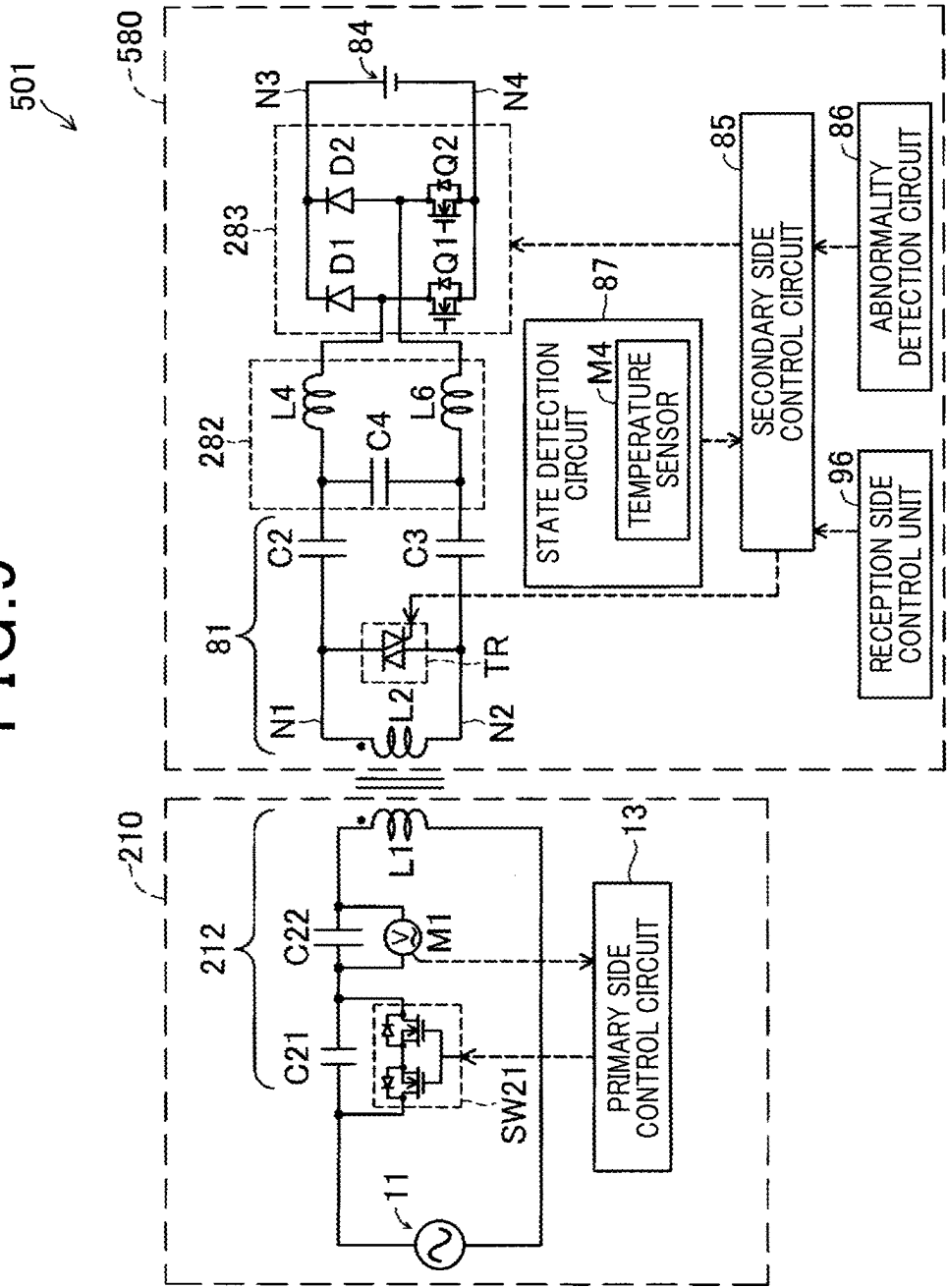
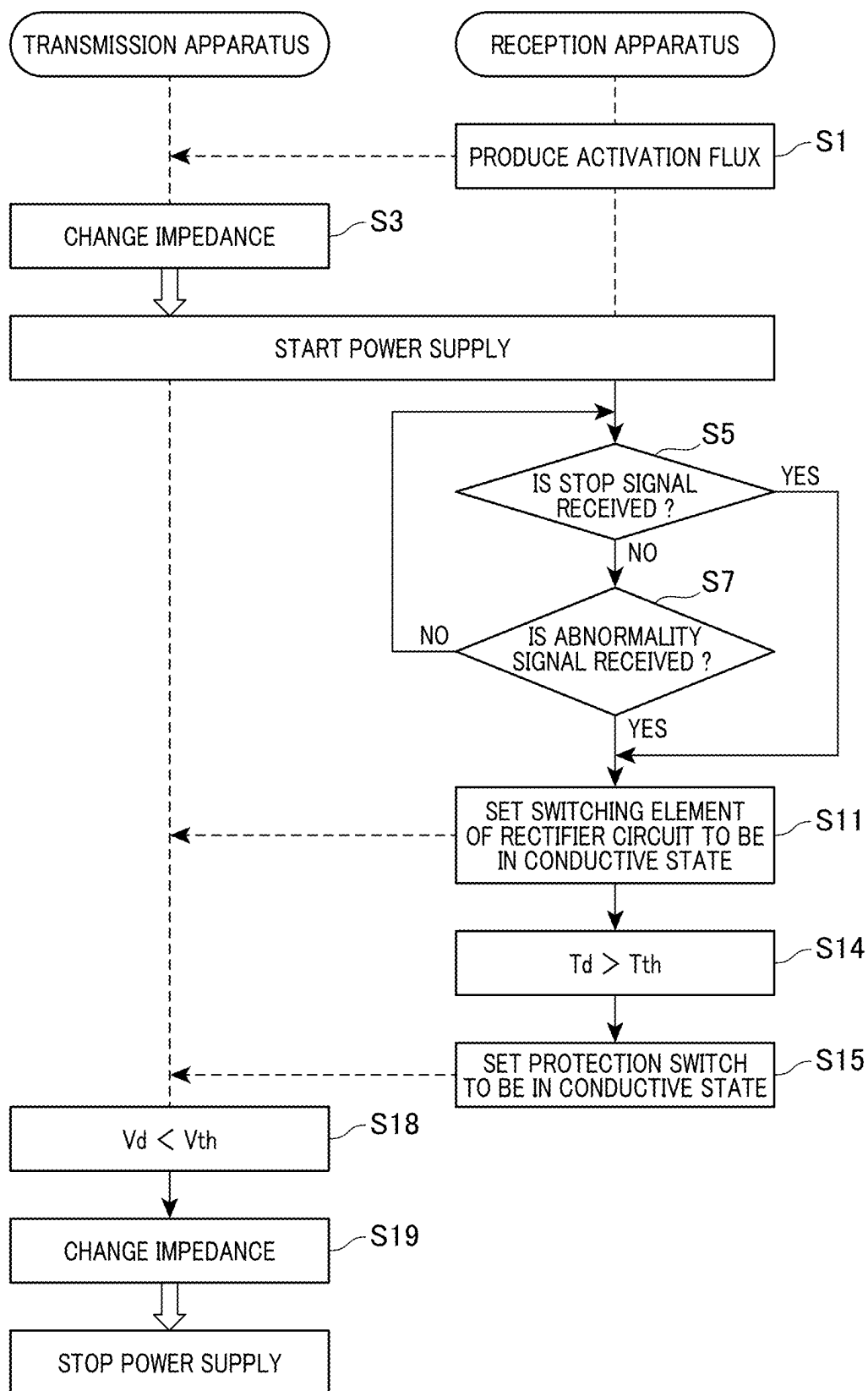


FIG.10



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

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.

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 L1 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 L1 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 L2 magnetically coupled to a primary coil L1, 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 L2 is disposed on a lower surface of the vehicle VE, facing the primary coil L1.

[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 C1, 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 C1 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 C1 is connected to a portion between the primary coil L1 and the AC power source 11. The primary capacitor C1 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 C1 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 C1 is changed, in response to a switch signal Sig1 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 L1 and the secondary coil are magnetically coupled to each other and the primary capacitor C1 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 C1 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 C1 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 L1 and the primary capacitor C1 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 L1. Specifically, the magnetic flux detection circuit 14 incorporates a detection coil Lsp disposed in the vicinity of the secondary coil L2, 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 Sig1 to the primary capacitor C1.

[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 L1. Specifically, the primary detection circuit may be a current sensor that detects current flowing through the primary coil L1 or a voltage sensor that detects voltage of the primary coil L1. Note that 'detecting magnitude of magnetic flux interlinking with the primary coil L1' refers to not only a case where entire magnetic flux interlinking with the primary coil L1 is detected but also a case where a part of the magnetic flux interlinking with the primary coil L1 is detected according to the present embodiment.

[0033] The reception apparatus 80 includes, in addition to the above-described configurations, secondary capacitors C2 and C3, an immittance circuit 82, a secondary side control circuit 85 and an abnormality detection circuit 86. The secondary capacitor C2 is series-connected to one end of the secondary coil L2 and the secondary capacitor C3 is series-connected to the other end of the secondary coil L2, 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 C2 or the secondary capacitor C3.

[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 L3 to L6 and a capacitor C4. The coils L3 and L4 are series-connected to a first feeding line N1 connected to one end of the secondary coil L2. The coils L5 and L6 are series-connected to a second feeding line N2 connected to the other end of the secondary coil L2. The capacitor C4 is connected to a connection point between the coil L3 and the coil L4 and a connection point between the coil L5 and the coil L6, and is connected in parallel to the coil L2.

[0036] The secondary resonant circuit 81 further includes a protection switch SW1. The protection switch SW1 is connected in parallel to the secondary coil L2. Thus, compared to a case where the protection switch SW1 is series-connected to the secondary coil L2, that is, the protection switch SW1 is inserted to the first feeding line N1 or the second feeding line N2, a power loss can be reduced and the rated current of the protection switch SW1 can be smaller. The conductive state of the protection switch SW1 causes the secondary resonant 81 to be in a non-resonant state. According to the present embodiment, the protection switch SW1 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 SW1 can be reduced.

[0037] The secondary side control circuit 85 changes the state of the protection switch SW1 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 Sig2 to be inputted to the gate terminals of two MOS FETs that constitutes the protection switch SW1, thereby changing the state of the protection switch SW1.

[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 L1 and the secondary coil L2 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 L1 and the secondary coil L2, 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 L1 are arranged in a direction where the road RS extends, the secondary coil L2 is supplied with power from the closest primary coil L1 in a contactless manner, that is, contactless power supply.

[0043] The transmission apparatus 10 causes a standby current to flow through the primary coil L1 in the standby state, thereby producing magnetic flux at the primary coil L1. When the secondary coil L2 approaches the primary coil L1, the reception apparatus 80 utilizes a secondary side detection circuit (not shown) to detect magnetic flux produced by the primary coil L1. The reception apparatus 80 produces, when detecting magnetic flux produced by the primary coil L1, activation flux at step S1 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 L1 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 L1, thereby detecting the closest primary coil L1.

[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 C1 as a variable impedance element at step S3 shown in FIG. 3. Specifically, the primary side control circuit 13 outputs the switch signal Sig1 to the primary capacitor C1. Thus, the capacitance value of the primary capacitor C1 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 L1, 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 L1. 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 C1 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 L1 is changed. During the power reception state of the reception apparatus 80, the protection switch SW1 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 S5 after activating the power reception. When determining that the stop signal is received, the secondary side control circuit 85 determines, at step S7, 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 S5.

[0047] On the other hand, when determining that the stop signal is received at step S5 and determining that an abnormality signal is received at step S7, the secondary side control circuit 85 sets the protection switch SW1 to be in the conductive state at step S15. In more detail, the secondary side control circuit 85 changes the state of the protection switch SW1 from the non-conductive state to the conductive state. Specifically, the secondary side control circuit 85 outputs a high level of signal Sig2 to the protection switch SW1. Thus, the protection switch SW1 is in the conductive state and one end of the secondary coil L1 and the other end of the secondary coil L2 are short-circuited. Hence, the impedance of the secondary resonant circuit 81 becomes higher and the current flowing through the secondary coil L2 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 L2 are short-circuited, thereby causing the secondary coil L2 to serve as a cancel coil that cancels the magnetic flux produced by the primary coil L1.

[0048] The impedance Z of the secondary resonant circuit 81 when the protection switch SW1 is in a non-conductive state is expressed by an equation (1), where an inductance of the secondary coil L2 is L, the capacitance of the secondary capacitor C2 is C/2, the capacitance of the secondary capacitor C3 is C/2, and the resistance of the resistance component of the secondary resonant circuit 81 is r.

$$Z = r + j(\omega L - 1/\omega C) \quad (1)$$

[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 SW1 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 L2 is lower than a current flowing through the secondary coil L2 in the case where the protection switch SW1 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 L1 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 S19, the switch signal Sig1 that changes the capacitance of the primary capacitor C1 to be the second capacitance, when determining, at step S17, that the detection value Bd of the magnetic flux density indicated by a signal outputted from the magnetic flux density 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 SW1. Hence, the protection switch SW1 is used to protect the battery 84 by lowering the current flowing through the secondary coil L2 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 L1 is small, the primary side control circuit 13 changes the capacitance of the primary capacitor C1 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 C21, a second capacitor C22 and a primary coil L1. The first capacitor C21 and the second capacitor C22 are connected in series to the primary coil L1. The capacitance of the first capacitor C21 is smaller than the capacitance of the second capacitor C22. Further, the transmission apparatus 210 includes a switch SW21 that bypasses the first capacitor C21. During a power-transmission state of the transmission apparatus 210, the switch SW21 as a variable impedance element is set to be in a conductive state. During a standby state of the transmission apparatus 210, the switch SW21 is set to be in a non-conductive state. In the case where the switch SW21 is set to be in the conductive state, the capacitance of the second capacitor C22 is set to be a value that allows the primary coil L1 to be in a resonant state at the operating frequency. Once the switch SW21 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 L1.

[0055] According to the present embodiment, instead of the magnetic flux detection circuit 14 of the first embodiment, a voltage sensor M1 as a primary detection circuit is provided. The voltage sensor M1 is used to detect a mag-

nitude of magnetic flux interlinking with the primary coil. Specifically, the voltage sensor M1 detects the voltage of the second capacitor C22 and outputs a signal indicating the detection value to the primary side control circuit 13. The detection value of the voltage sensor M1 is a voltage value such that the larger the current value flowing through the primary coil L1, the larger the voltage value is. Therefore, similar to the first embodiment, current flowing through the secondary coil L2 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 L3 and the coil L5 of the immittance circuit 83 of the first embodiment are not provided. According to the present embodiment, a leakage inductance of the secondary coil L2 is utilized similar to the coil L3 and the coil L5 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 L2, the coils L4 and L6 and the capacitor C4.

[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 D1 and D2, and switching elements Q1 and Q2 as a switch. The diodes D1 and D2 constitute an upper arm connected to a positive electrode side supply line N3 connected to the positive electrode of the battery 84. The switching elements Q1 and Q2 constitute a lower arm connected to a negative electrode side supply line N4 connected to the negative electrode of the battery 84. The switching elements Q1 and Q2 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 Q1 and Q2. According to the present embodiment, the switching elements Q1 and Q2 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 S5 and determining that an abnormality signal is received at step S7, the secondary side control circuit 85 sets, at step S11, the switching elements Q1 and Q2 of the rectifier circuit 283 to be in the conductive state. Thus, since the first feeding line N1 and the second feeding line N2 are short-circuited via the switching elements Q1 and Q2, 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 Q1 and Q2 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 Q1 and Q2 from being applied with excessive current and voltage.

[0059] The secondary side control circuit 85 changes, at step S15, 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 L2 can be

reduced. The states of the switching elements Q1 and Q2 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 S19, a high level signal for setting the switch SW21 to be in a conductive state, when determining, at step S17, that the voltage value Vd indicated by the signal outputted from the voltage sensor M1 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 SW1 is being changed to be in a conductive state, the switching elements Q1 and Q2 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 C31 is connected in parallel to a primary coil L1. The transmission apparatus 310 according to the present embodiment further includes a resistor R1. The resistor R1 is connected in series to the primary coil L1.

[0064] According to the present embodiment, the voltage sensor M1 as the primary detection circuit detects the voltage across the resistor R1 and outputs the signal indicating the detection value to the primary side control circuit 13. The detection value of the voltage sensor M1 changes such that the larger the current value of the current flowing through the primary coil L1, the larger the detection value is. Hence, similar to the first embodiment, current flowing through the secondary coil L2 in the reception apparatus 280 can be prevented from decreasing. The transmission apparatus 310 may include a coil instead of the resistor R1. In this case, the voltage sensor M1 detects voltage across the coil.

[0065] According to the present embodiment, the switch SW31 as the variable impedance element is connected in series to the primary coil L1. 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 C3. The semiconductor relay RE may be connected to bypass the secondary capacitor C2 not the secondary capacitor C3.

[0067] As shown in FIG. 7, when determining that the stop signal is received at step S5, or determining that an abnormality signal is received at step S7, the secondary side

control circuit **85** sets, at step **S13**, the switching elements **Q1** and **Q2** 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 **S15**. Since the semiconductor relay **RE** is connected in parallel to the secondary capacitor **C3**, assuming that the semiconductor relay **RE** changes the state to be in the conductive state during the switching elements **Q1** and **Q2** of the rectifier circuit **28** being in the conductive state, excessive current possibly flows through the secondary coil **L2**. In this respect, the semiconductor relay **RE** is changed to be in the conductive state during the switching elements **Q1** and **Q2** being in the non-conductive state. Hence, the secondary coil **L2** 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 **Q1** and **Q2** being in the non-conductive state, whereby the secondary coil **L2** 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 **L41** and the capacitor **C42** are connected in series. The coil **L41** is disposed in a location capable of being magnetically coupled with the primary coil **L1**. 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 **L1** to be smaller in the case where a distance between the primary coil **L1** and the secondary coil **L2** is long and a coupling coefficient between the primary coil **L1** and the secondary coil **L2** is small. In more detail, the capacitance of the primary capacitor **C1** 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 **L1** and the second coil **L2** 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 **L1** and the secondary coil **L2** 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 **L1** and the secondary coil **L2** is small, the inductance of the primary resonant circuit **12** is large and the current flowing through the primary coil **L1** becomes small.

[0072] The reception apparatus **480** includes two protection switches **SW41** and **SW42**. The protection switches **SW41** and **SW42** are semiconductor switches. According to the present embodiment, the protection switches **41** and **42** are integrated into a single MOSFET. The protection switch

SW41 is inserted into the first feeding line **N1**. The protection switch **SW42** is inserted into the second feeding line **N2**.

[0073] As other embodiments of the protection switches **SW41** and **SW42**, 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 **N1** or the second feeding line **N2**.

[0074] The rectifier circuit **483** includes two diodes that constitute the lower arm, and two switching elements **Q1** and **Q2**.

[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 **SW1** and **SW2** 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 **SW41** and **SW42** 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 **L2** decreases. In this case, when viewing from the primary resonant circuit **12** side, it can be presumed that the secondary coil **L2** is not present. Hence, the current I_1 flowing through the primary resonant circuit **12** is expressed by an equation (2).

$$I_1 = r_3 / (\omega^2 \cdot L_{13}^3) \cdot V_1 \quad (2)$$

In the equation (2), r_3 is winding resistance of the coil **41**, L_{13} is a mutual inductance between the primary coil **L1** and the coil **L41**, V_1 is an output voltage of the AC power source **11**. In the equation (2), since the denominator ' $\omega^2 \cdot L_{13}^3$ ' is sufficiently larger than the numerator ' r_3 ', the current I_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 **M4**. The temperature sensor **M4** is disposed in the vicinity of the immittance circuit **282**. Note that, the temperature sensor **M4** may not be disposed in the vicinity of the immittance circuit **282** but may be disposed in the vicinity of the switching elements **Q1** and **Q2**, and may detect the temperature in the vicinity of the switching element **Q1** and **Q2**.

[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 T_d is higher than a predetermined reference temperature T_{th} .

[0081] As shown in FIG. 10, the secondary side control circuit **85** sets, at step **S11** as a first process, the switching elements **Q1** and **Q2** of the rectifier circuit **283** to be in the conductive state. Then, when determining that the detected temperature T_d of the temperature sensor **M4** is higher than the reference temperature T_{th} at step **S14**, 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 **S15**. [0082] At step **S11**, in the case where the switching elements **Q1** and **Q2** of the rectifier circuit **283** are set to be in the conductive state, as described above, the current flowing through the secondary coil **L2** 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 **L1**, the detection value of the voltage sensor **M1** 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 **L1**, 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 T_d of the temperature sensor **M4** is higher than the reference temperature T_{th} at step **S14**, 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 **Q1** and **Q2** 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 T_d of the temperature sensor **M4** is not higher than the reference temperature T_{th} , since the transmission apparatus **210** is already moved to the standby state after setting the switching elements **Q1** and **Q2** of the rectifier circuit **283** to be in the conductive state, the secondary side control circuit **85** does not change the protection switch **SW1** 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 **M4** is higher than the reference temperature T_{th} and the power-supply current continues to flow through the secondary coil **L2**, the triac **TR** is changed to be in the non-conductive state at step **S15**, thereby causing the transmission apparatus **210** to be in the standby state.

F. Other Embodiments

[0084] (F1) According to the above-described first embodiment, so-called S-S type circuit configuration is employed in which the primary capacitor **C1** is connected in series to the primary coil **L1** in the primary resonant circuit **12**, and the secondary capacitor **C2** is connected in series to the secondary coil **L2** 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 **C1** is connected in parallel to the primary coil **L1** in the primary

resonant circuit **12**, and the secondary capacitor **C2** is connected in series to the secondary coil **L2** 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 **L1** is provided in addition to the primary capacitor **C1** connected in series to the primary coil **L1**, and two secondary capacitors **C2** are each connected in series to each of the both terminals of the secondary coil **L2** 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 **L2** in the case where the primary coil **L1** and the secondary coil **L2** 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 **L1** 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 **L2** in the case where the primary coil **L1** and the secondary coil **L2** are magnetically coupled.

[0090] (F2) According to the above-described second embodiment, the switching elements **Q1** and **Q2** included in the rectifier circuit **83** are embodied by MOSFETs. As other embodiment, the switching elements **Q1** and **Q2** 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 **Q1** and **Q2**, 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 **L2** from the battery **84**. In this respect, at step **S1**, AC power may be applied to the secondary coil **L2**, whereby the secondary coil **L2** 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 T_d is higher than the predetermined reference temperature T_{th} . As other embodiment of the state detection circuit **87**, the detection temperature T_d detected by the temperature sensor **M4** at step **S11** 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 L2 or voltage of the secondary coil L2 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 L2 or the voltage of the secondary coil L2 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 (L1) and a primary capacitor (C1);
 - [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 (C1, SW21, SW31) 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, M1) 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 (L2) to be magnetically coupled with the primary coil, and a secondary capacitor (C2, C3);

- [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 (SW1, TR, RE, SW41, SW42) 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 (Q1, Q2) 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 (Q1, Q2) 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 (L1) and a primary capacitor (C1);

[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 (SW21) 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 (M1) 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 (L2) to be magnetically coupled with the primary coil, and a secondary capacitor (C2, C3);

[0138] a rectifier circuit (283) that rectifies an AC power outputted from the secondary resonant circuit, including a rectifier switch (Q1, Q2) 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 (S11) 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 (T_{th}).

(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 (L1) and a primary capacitor (C1);

[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 (C1, SW21, SW31) 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, M1) 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 (L2) to be magnetically coupled with the primary coil, and a secondary capacitor (C2, C3);

[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 (SW1, TR, RE, SW41, SW42) 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 (L1) and a primary capacitor (C1);

[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 (C1, SW21, SW31) 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, M1) 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 (L2) to be magnetically coupled with the primary coil, and a secondary capacitor (C2, C3);

[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 (SW1, TR, RE, SW41, SW42) 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 vari-

able 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, 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.

What is claimed is:

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.

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