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(54) **WIRELESS POWER TRANSMITTING APPARATUS AND METHOD THEREOF**

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(*) Notice: This patent is subject to a terminal disclaimer.

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Filed: **Dec. 28, 2015**

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CPC ***H02J 50/80*** (2016.02); ***H02J 50/10*** (2016.02); ***H02J 50/12*** (2016.02); ***H04B 5/79*** (2024.01)

(58) **Field of Classification Search**
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(Continued)

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Primary Examiner — My Trang Ton
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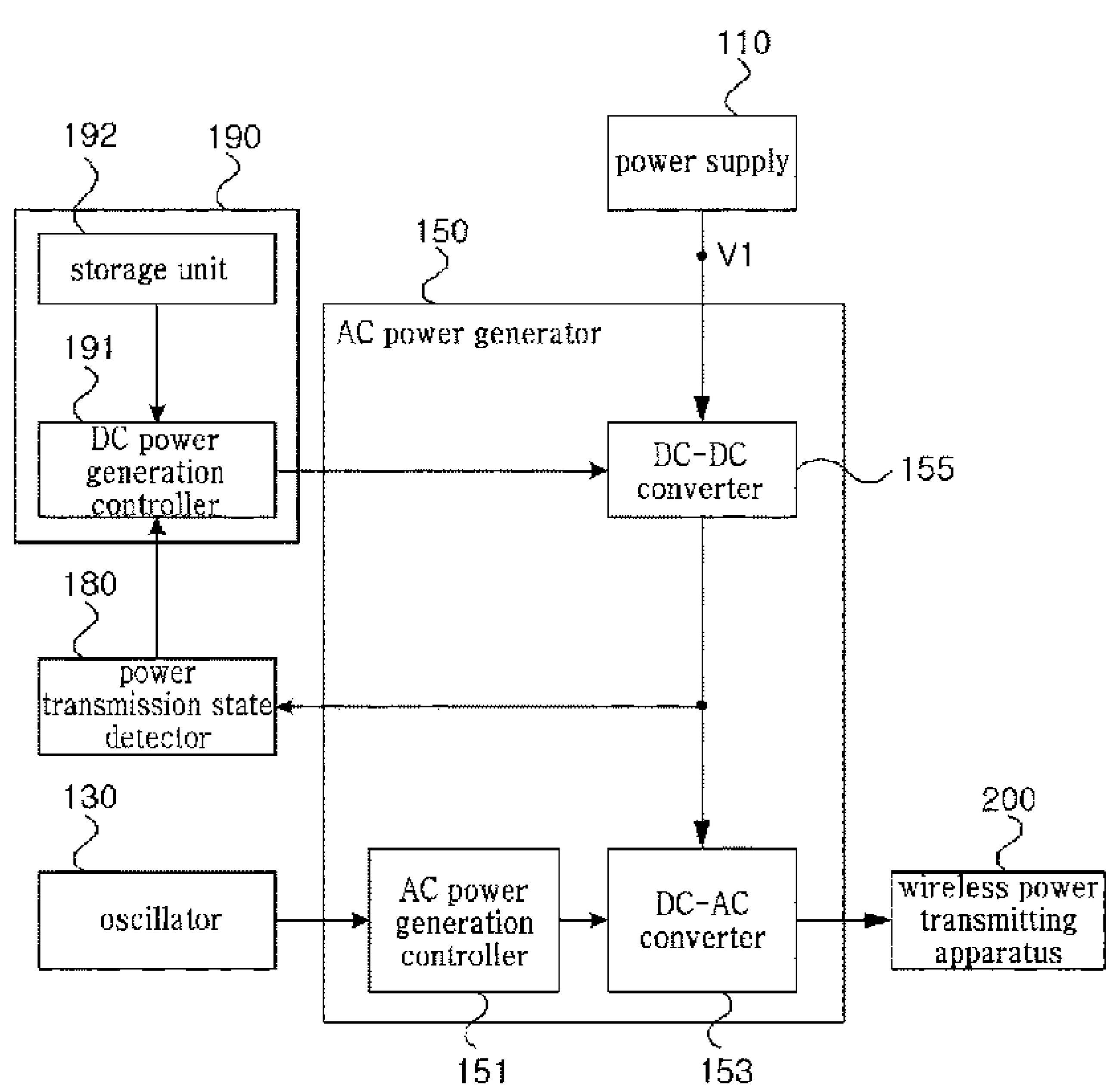
(57) **ABSTRACT**

Disclosed are a wireless power transmitting apparatus and a method thereof. The wireless power transmitting apparatus wirelessly transmits power to a wireless power receiving apparatus. The wireless power transmitting apparatus detects a wireless power transmission state between the wireless power transmitting apparatus and the wireless power receiving apparatus, and generates a control signal to control transmit power based on the detected wireless power transmission state. The wireless power transmitting apparatus generates the transmit power by using first DC power based on the control signal, and transmits the transmit power to a transmission resonance coil through a transmission induction coil unit based on an electromagnetic induction scheme.

20 Claims, 15 Drawing Sheets



Related U.S. Application Data

application for the reissue of Pat. No. 9,711,974, which is a continuation of application No. 13/826,526, filed on Mar. 14, 2013, now Pat. No. 9,225,391.

(51) **Int. Cl.**

H02J 50/10	(2016.01)
H02J 50/12	(2016.01)
H02J 50/80	(2016.01)
H04B 5/79	(2024.01)

(58) **Field of Classification Search**

CPC H01F 38/14; B60L 11/182; H04W 52/24; H04W 52/50; H04W 52/367; H04W 52/12; H04W 52/40; H01S 3/302; H01S 3/06754; H01S 3/094096; H01S 3/06758

USPC 307/104; 455/522; 359/334

See application file for complete search history.

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FIG. 1

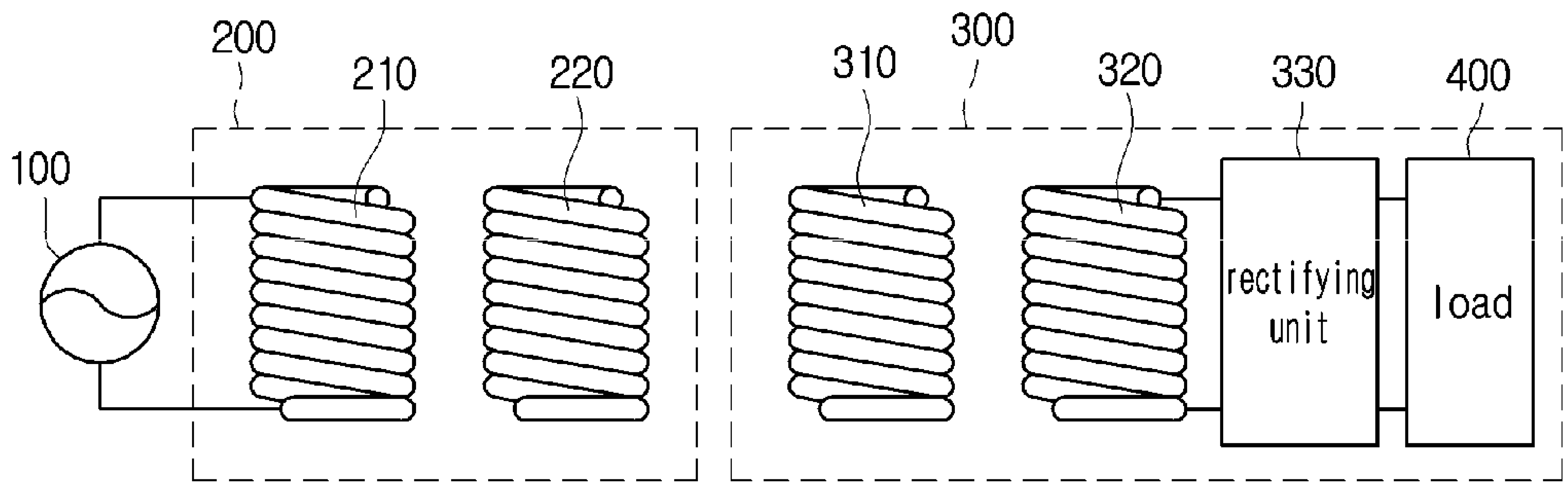


FIG.2

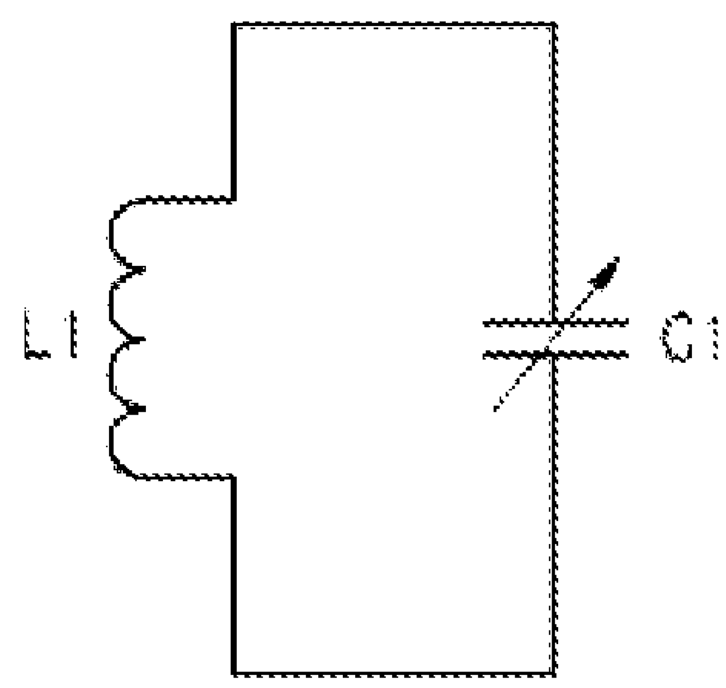


FIG.3

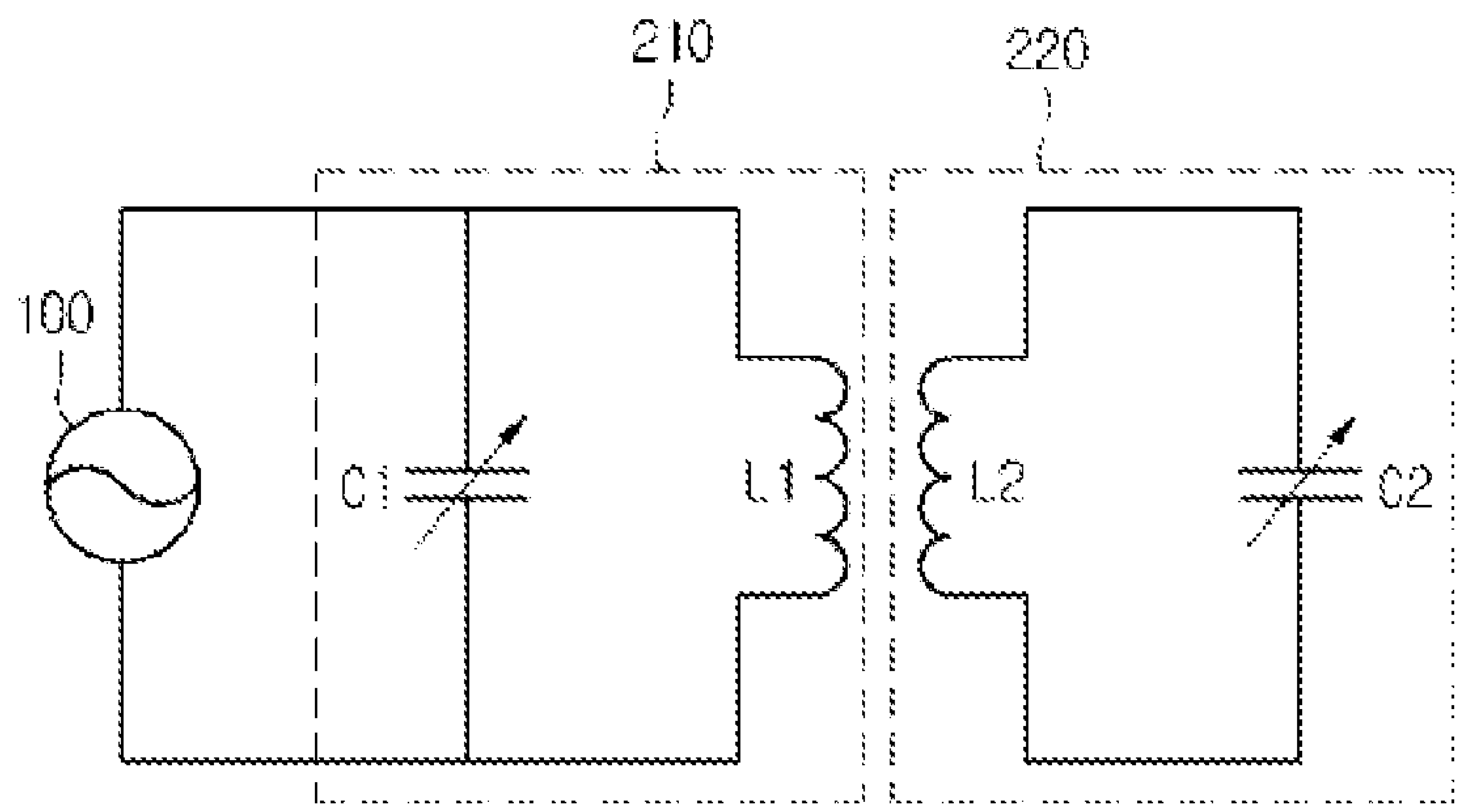


FIG. 4

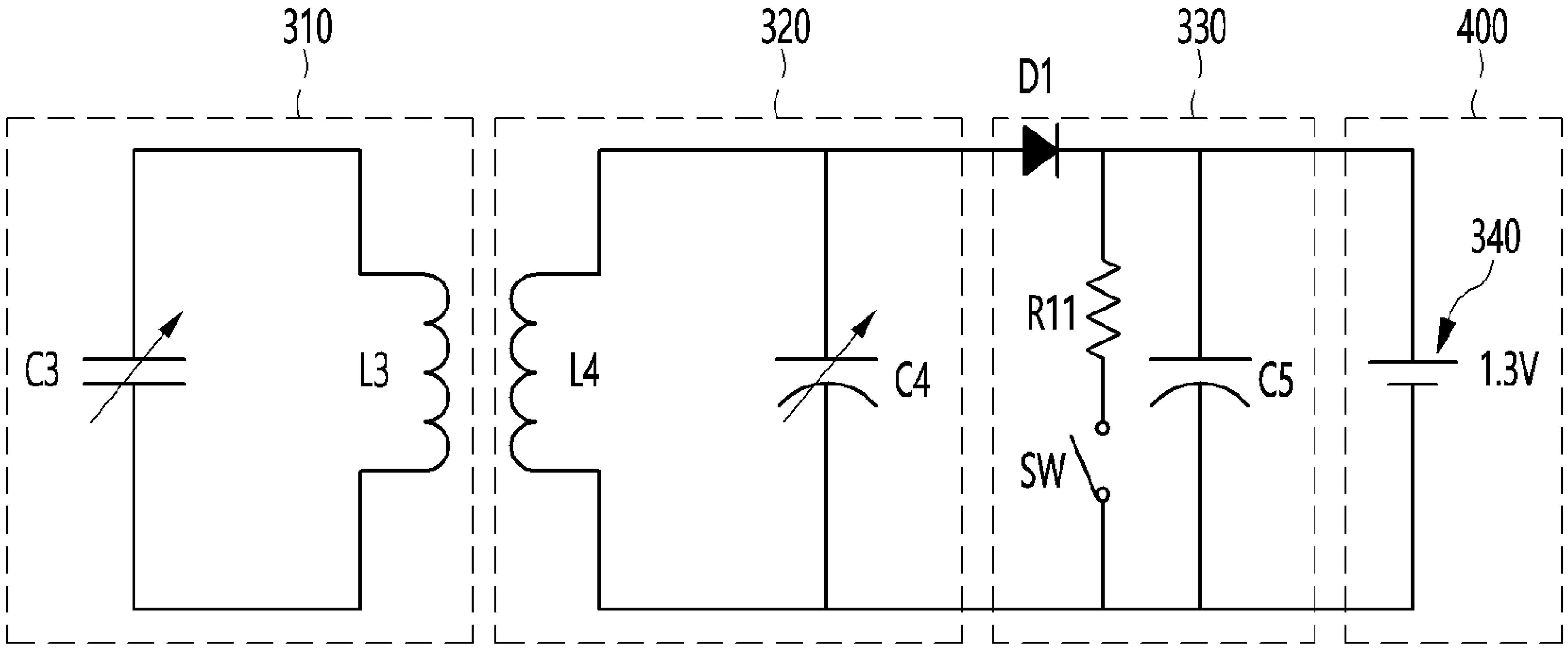

310
320
330
400
D1
340
C3
L3
L4
C4
R11
C5
SW
1.3V

FIG.5

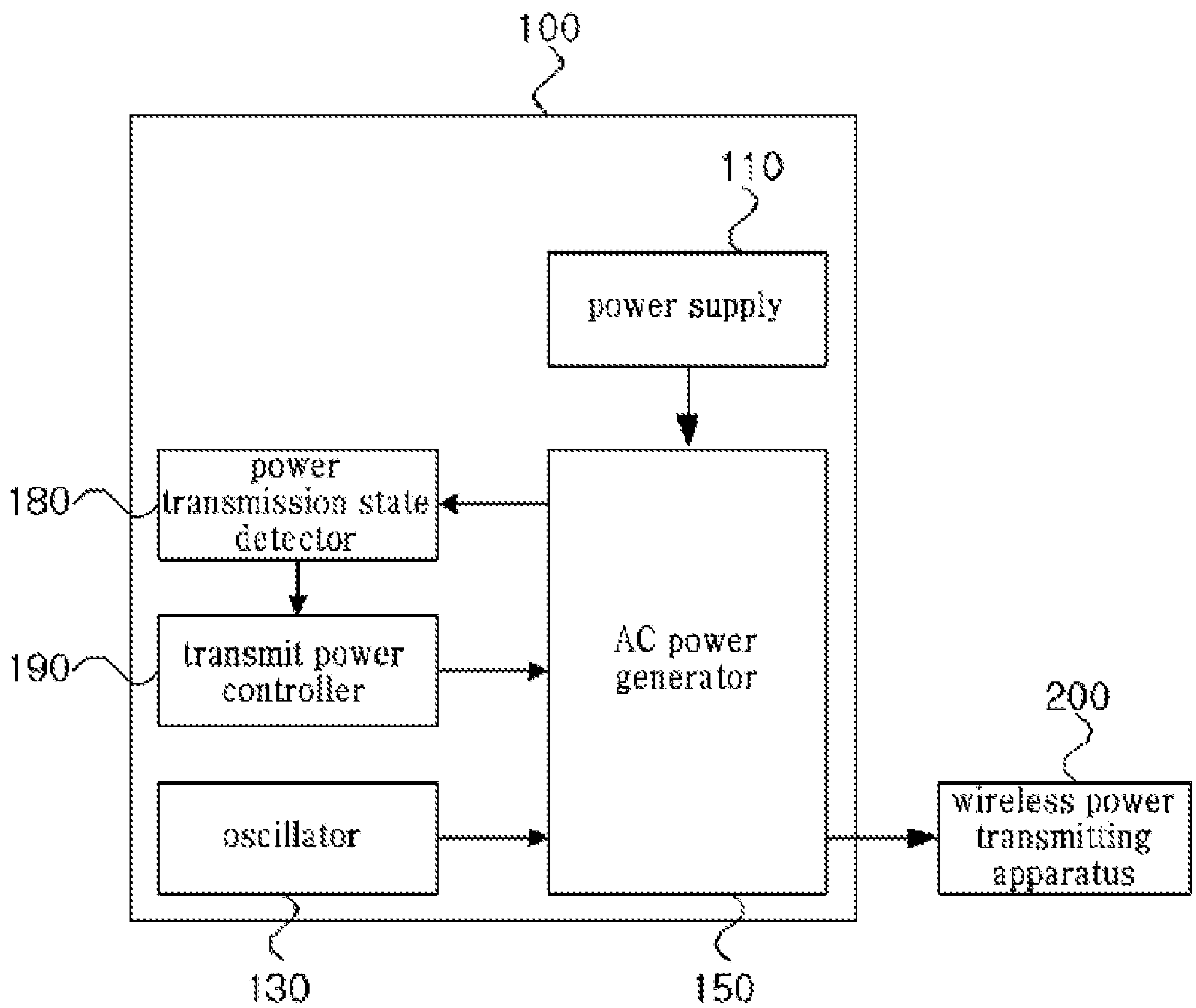

100
110
power supply
180
power transmission state detector
190
transmit power controller
AC power generator
oscillator
200
wireless power transmitting apparatus
130
150

FIG.6

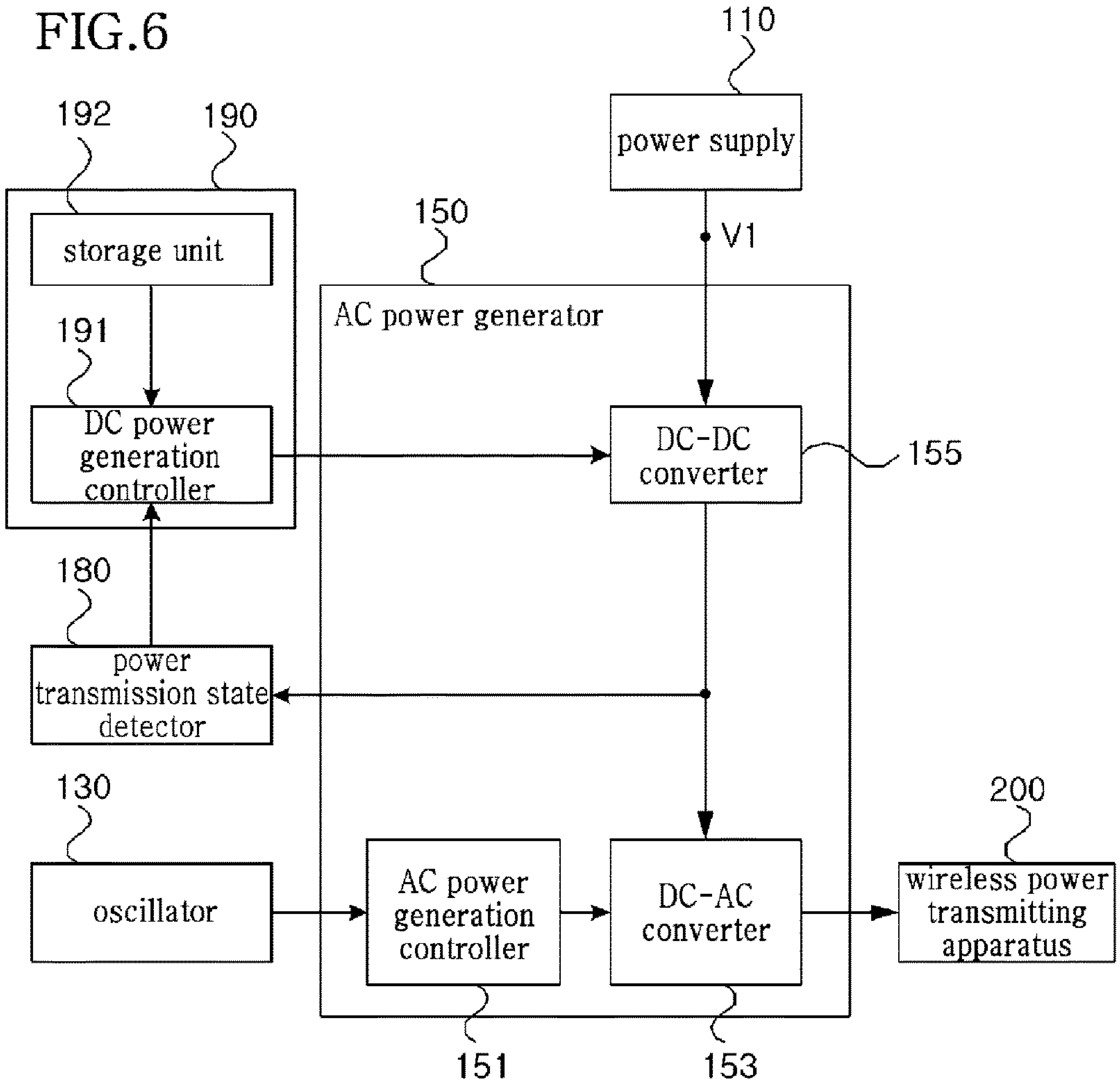

110
power supply
V1
192
190
storage unit
191
DC power generation controller
150
AC power generator
DC-DC converter
155
180
power transmission state detector
130
oscillator
AC power generation controller
DC-AC converter
200
wireless power transmitting apparatus
151
153

FIG.7

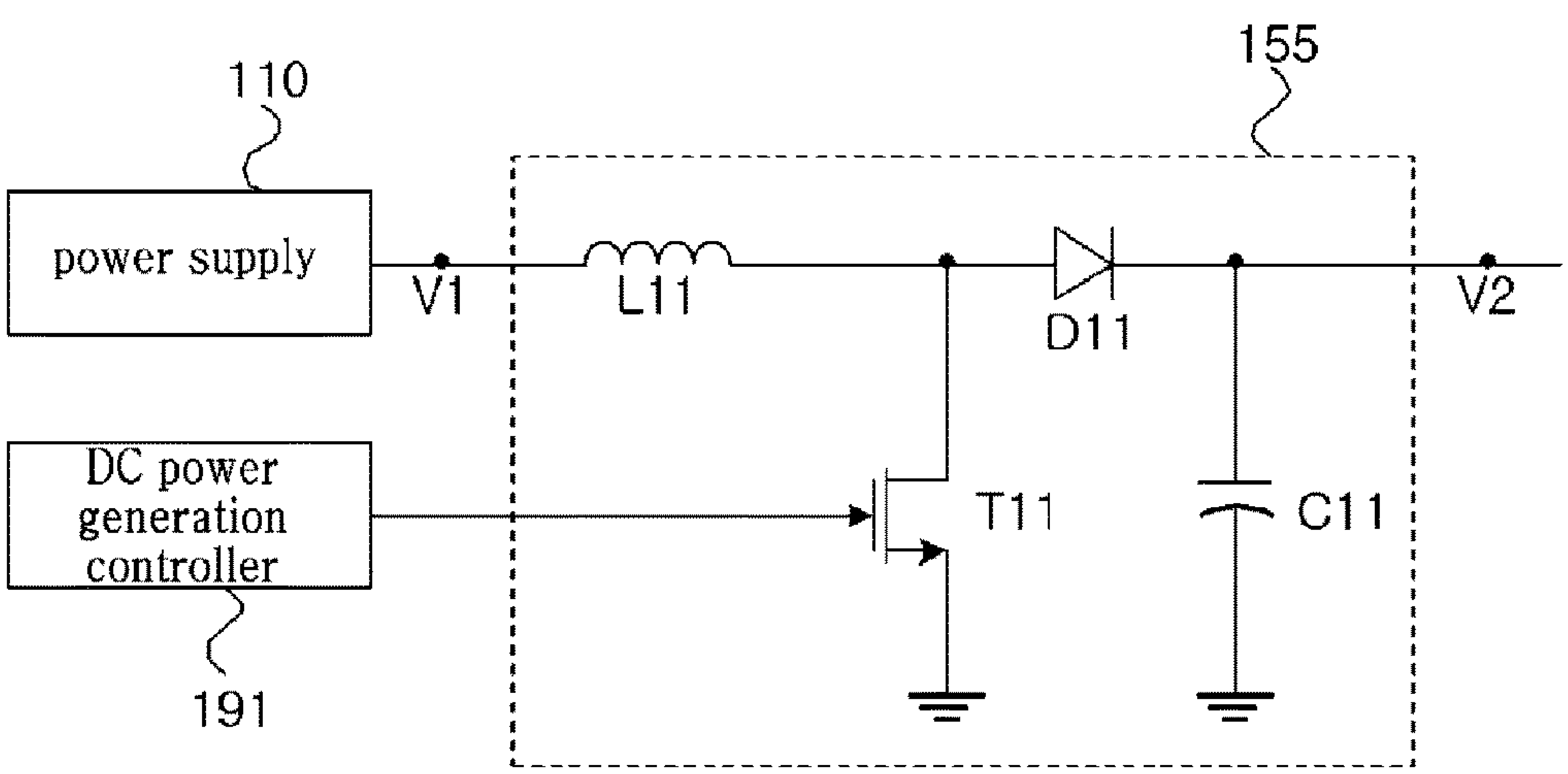

110
power supply
V1
L11
155
D11
V2
DC power generation controller
T11
C11
191

FIG.8

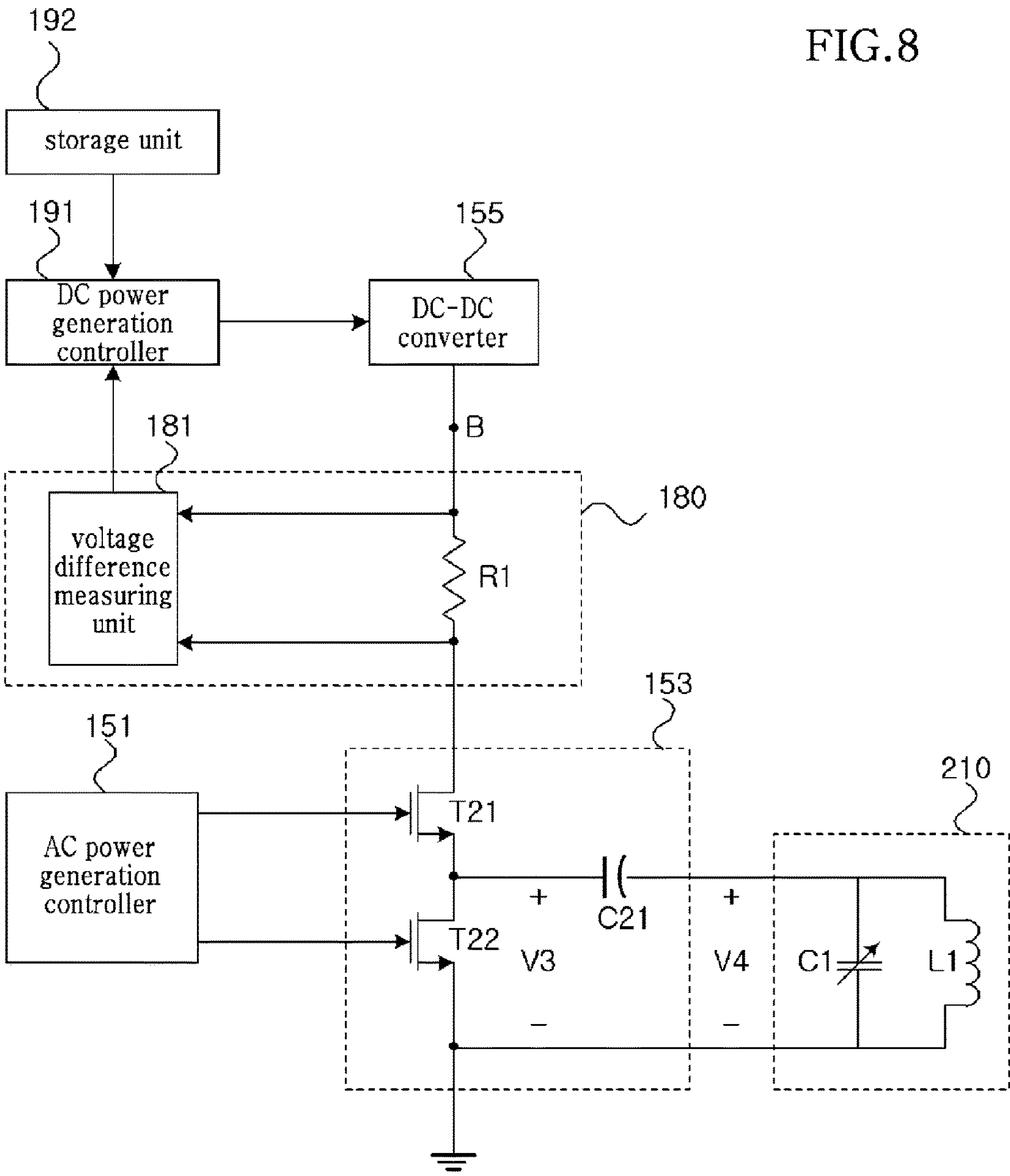

192
storage unit
191
DC power generation controller
155
DC-DC converter
B
181
180
voltage difference measuring unit
R1
153
151
AC power generation controller
T21
T22
C21
V3
V4
210
C1
L1
+
+
–
–

FIG.9

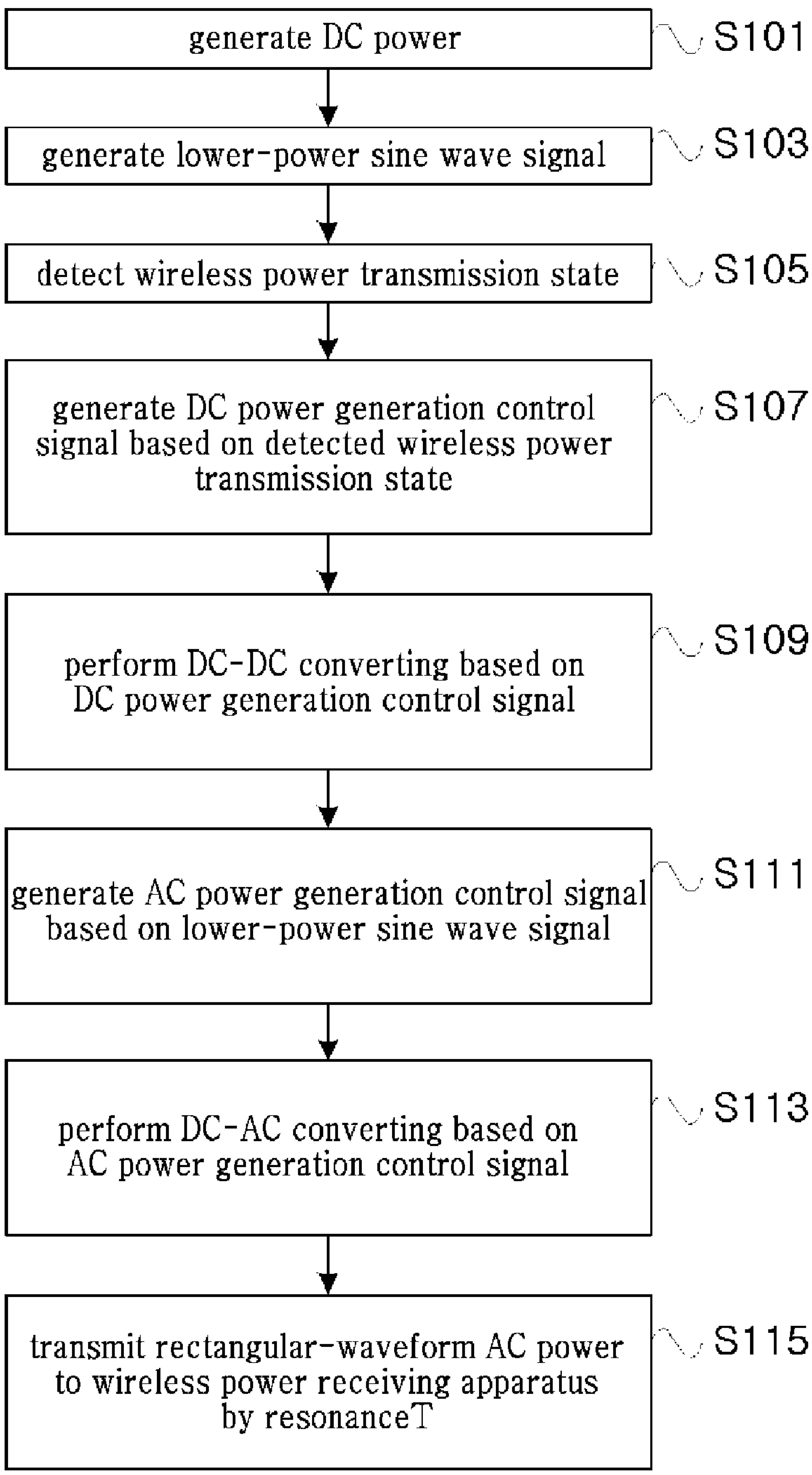

generate DC power
S101
generate lower-power sine wave signal
S103
detect wireless power transmission state
S105
generate DC power generation control signal based on detected wireless power transmission state
S107
perform DC-DC converting based on DC power generation control signal
S109
generate AC power generation control signal based on lower-power sine wave signal
S111
perform DC-AC converting based on AC power generation control signal
S113
transmit rectangular-waveform AC power to wireless power receiving apparatus by resonanceT
S115

FIG.10

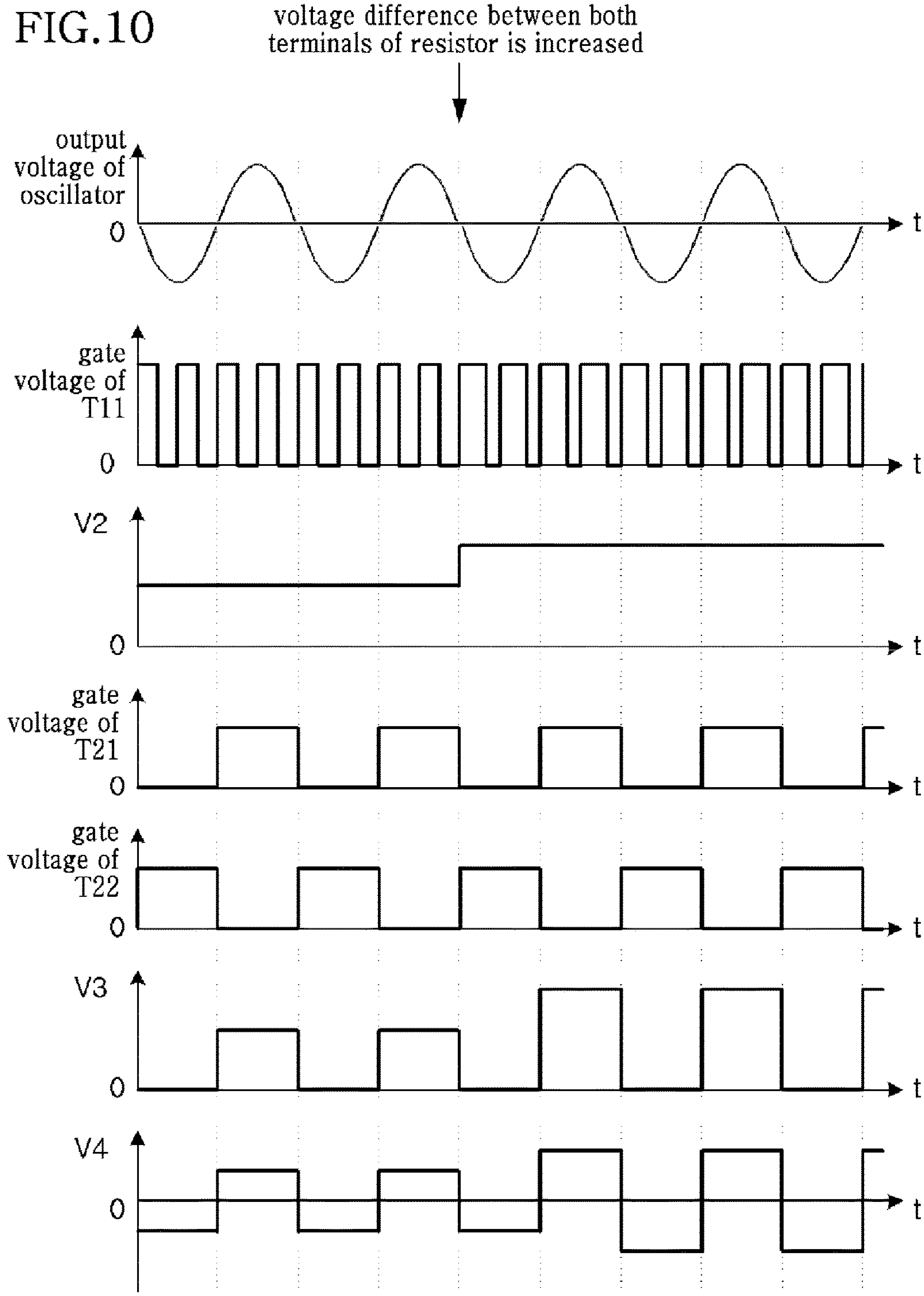

voltage difference between both terminals of resistor is increased
output voltage of oscillator
0
t
gate voltage of T11
0
t
V2
0
t
gate voltage of T21
0
t
gate voltage of T22
0
t
V3
0
t
V4
0
t

FIG.11

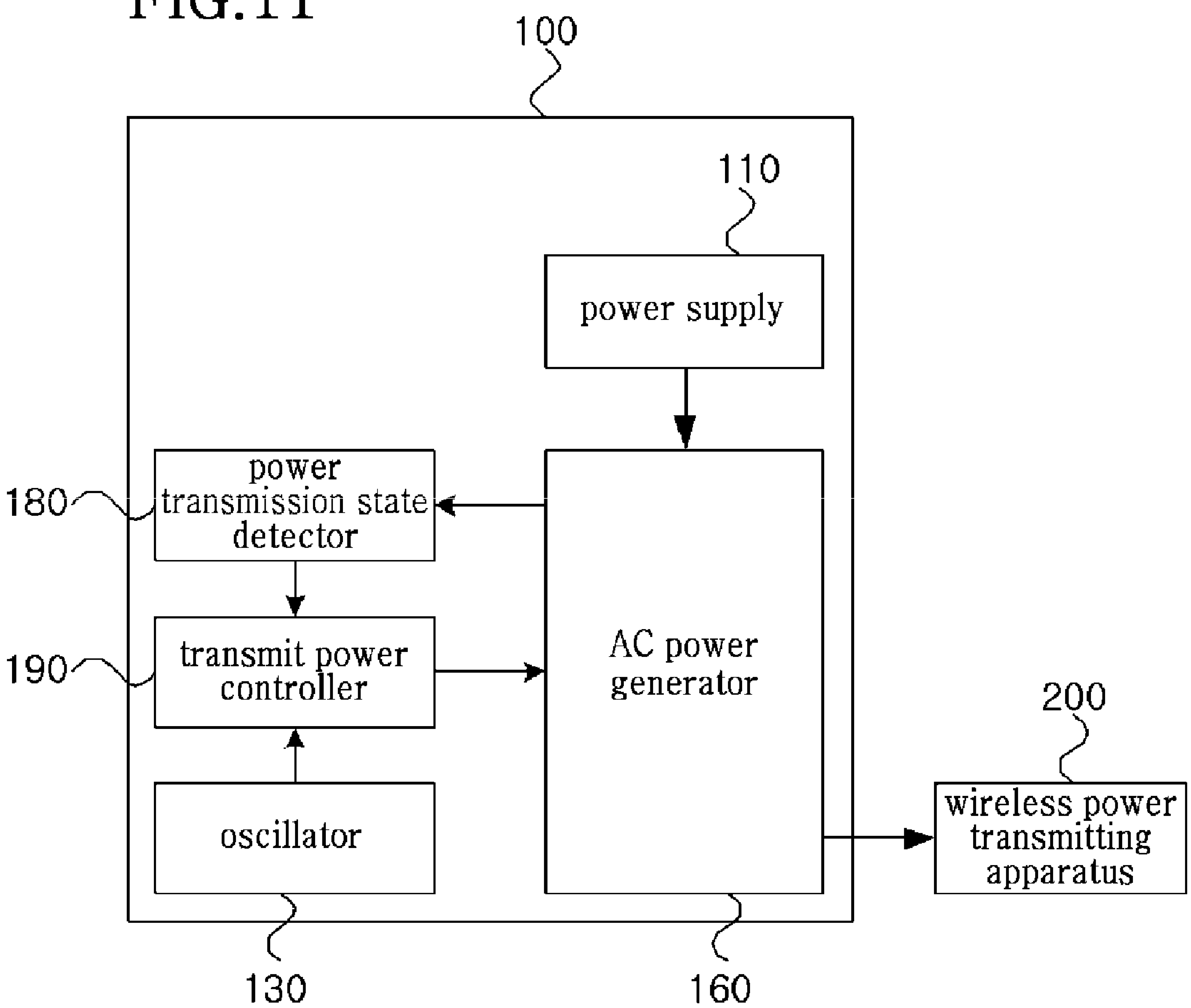

100
110
power supply
180
power transmission state detector
190
transmit power controller
AC power generator
200
wireless power transmitting apparatus
oscillator
130
160

FIG.12

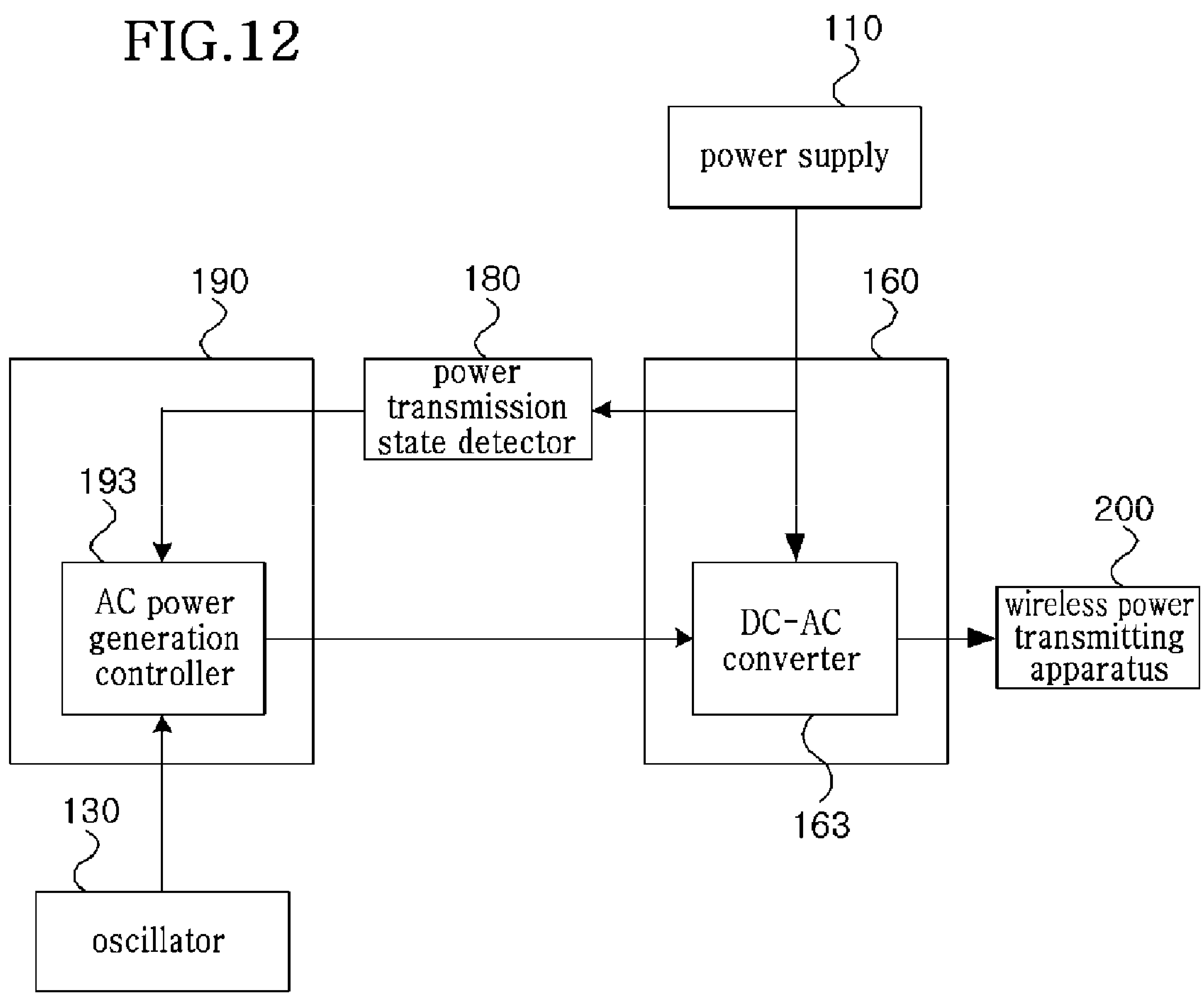

110
power supply
190
180
power transmission state detector
160
193
AC power generation controller
DC-AC converter
200
wireless power transmitting apparatus
163
130
oscillator

FIG.13

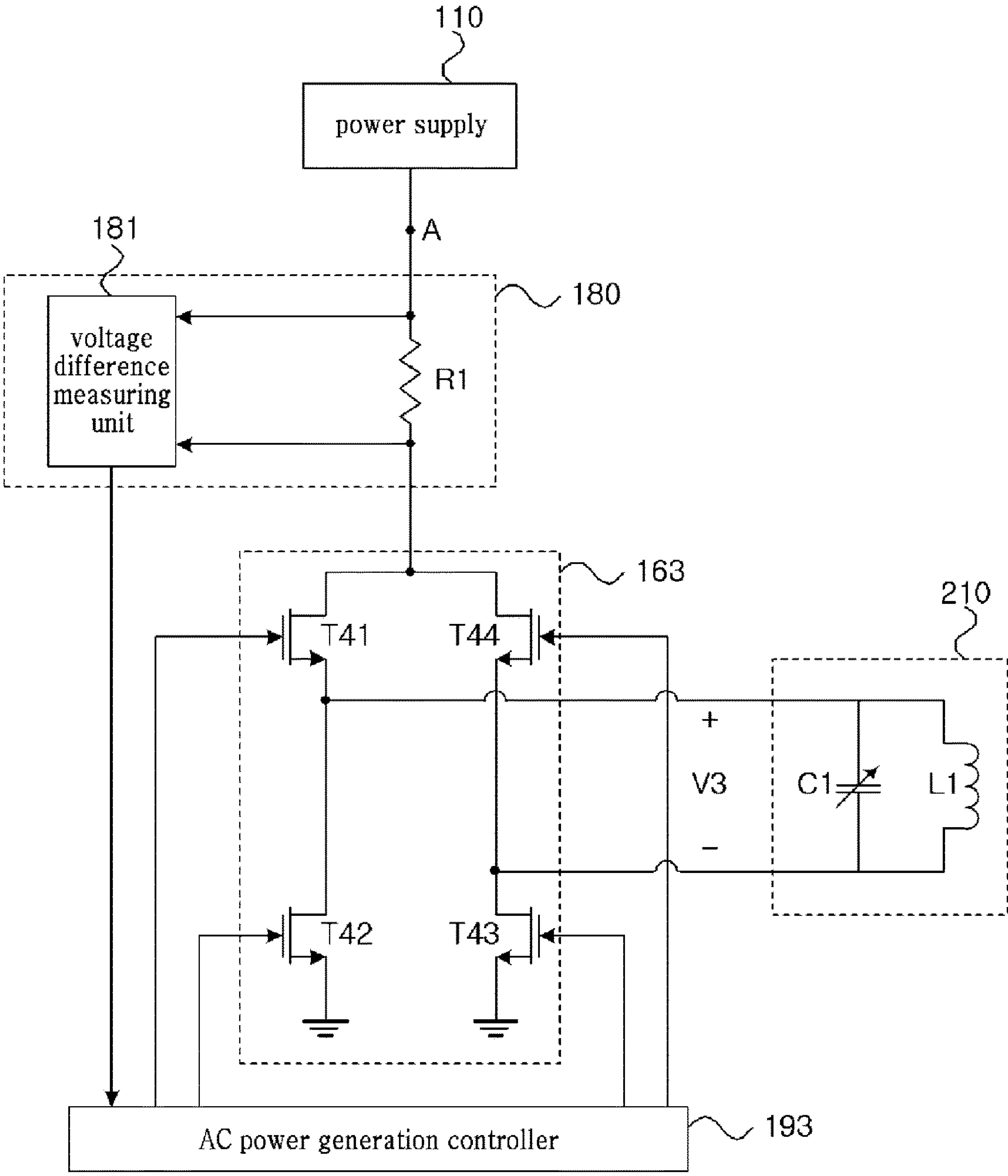

110
power supply
A
181
180
voltage difference measuring unit
R1
163
T41
T44
210
+
V3
C1
L1
−
T42
T43
AC power generation controller
193

FIG.14

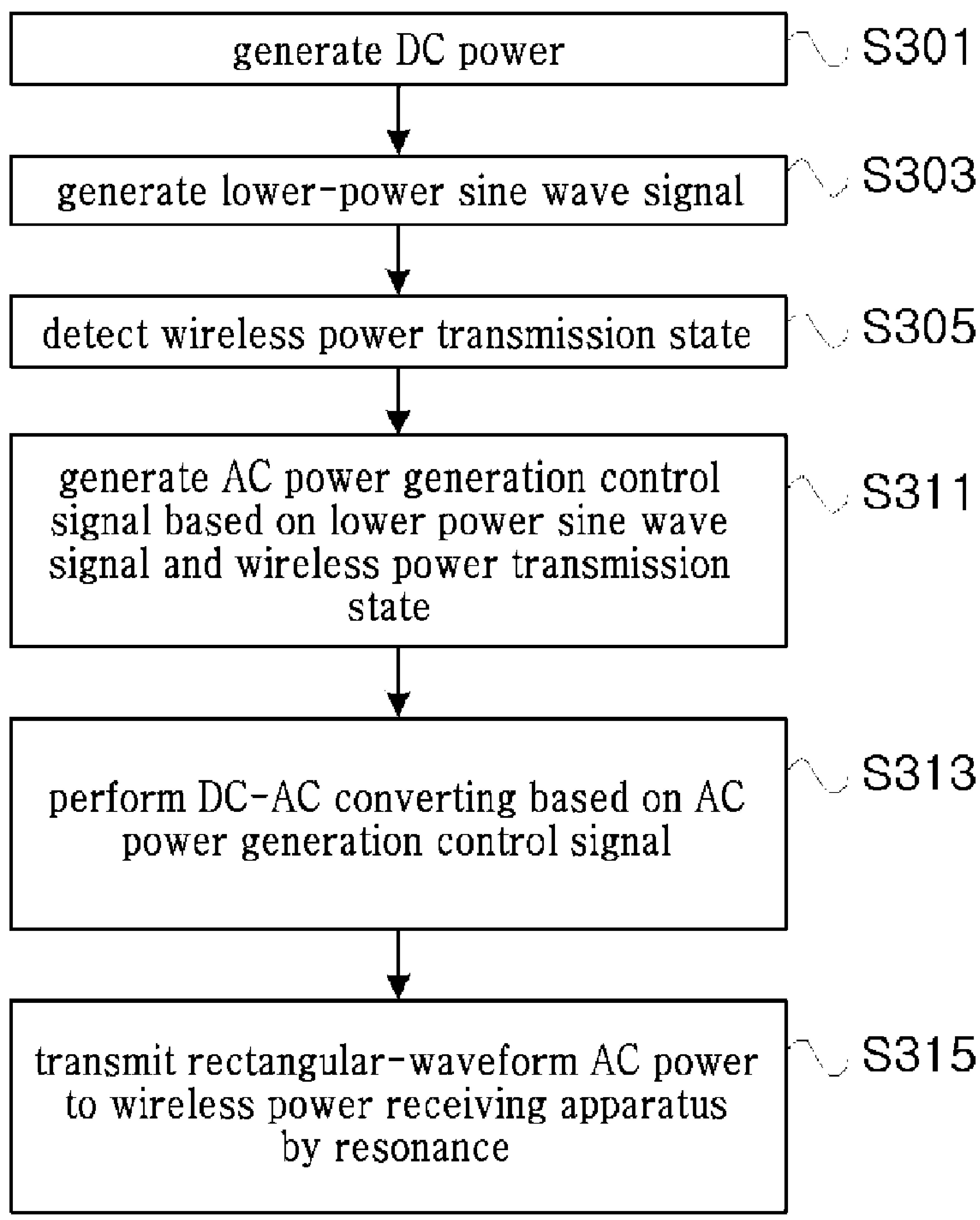

generate DC power
S301
generate lower-power sine wave signal
S303
detect wireless power transmission state
S305
generate AC power generation control signal based on lower power sine wave signal and wireless power transmission state
S311
perform DC-AC converting based on AC power generation control signal
S313
transmit rectangular-waveform AC power to wireless power receiving apparatus by resonance
S315

FIG.15

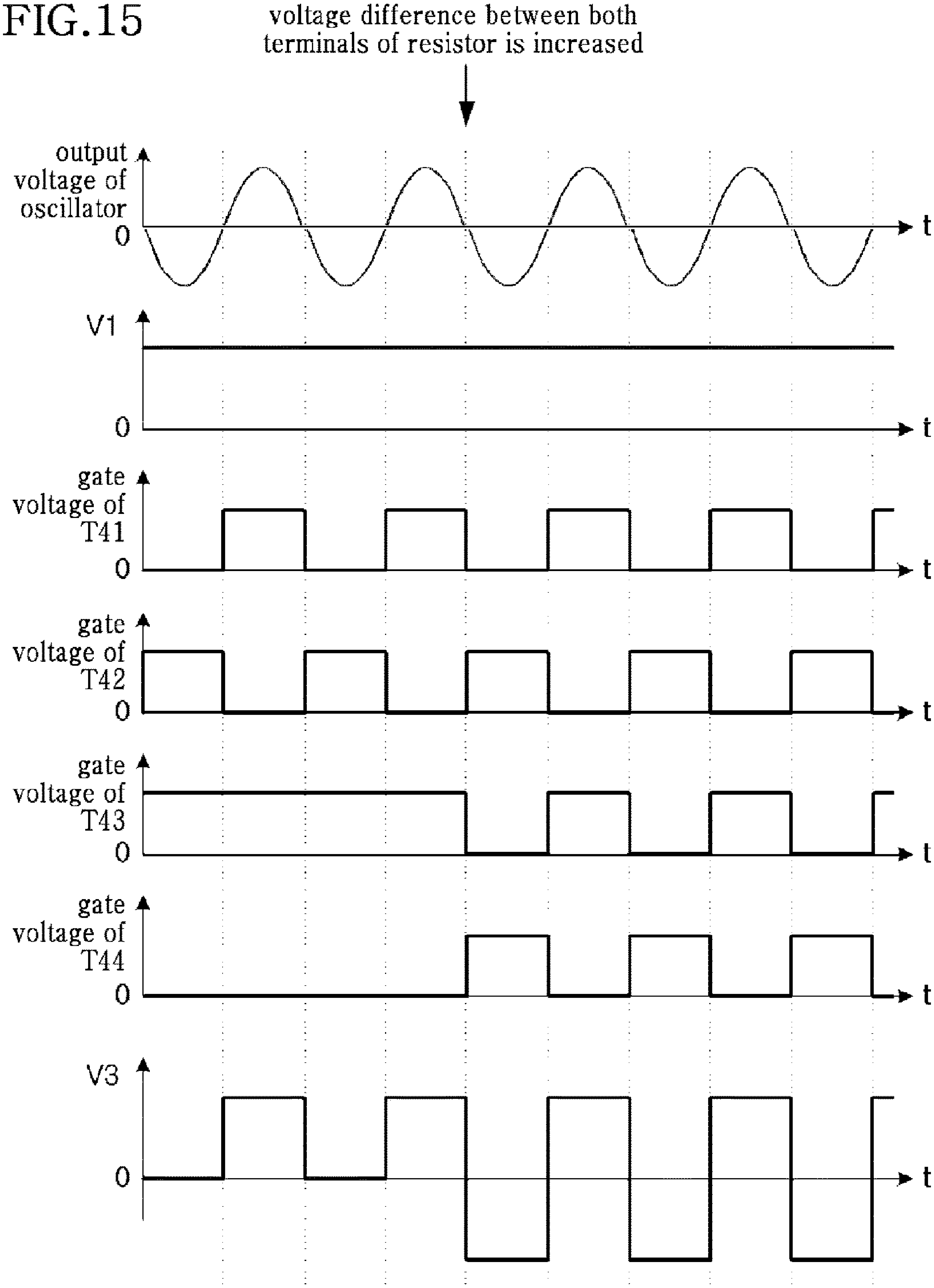

voltage difference between both terminals of resistor is increased
output voltage of oscillator
0
t
V1
0
t
gate voltage of T41
0
t
gate voltage of T42
0
t
gate voltage of T43
0
t
gate voltage of T44
0
t
V3
0
t

FIG.16

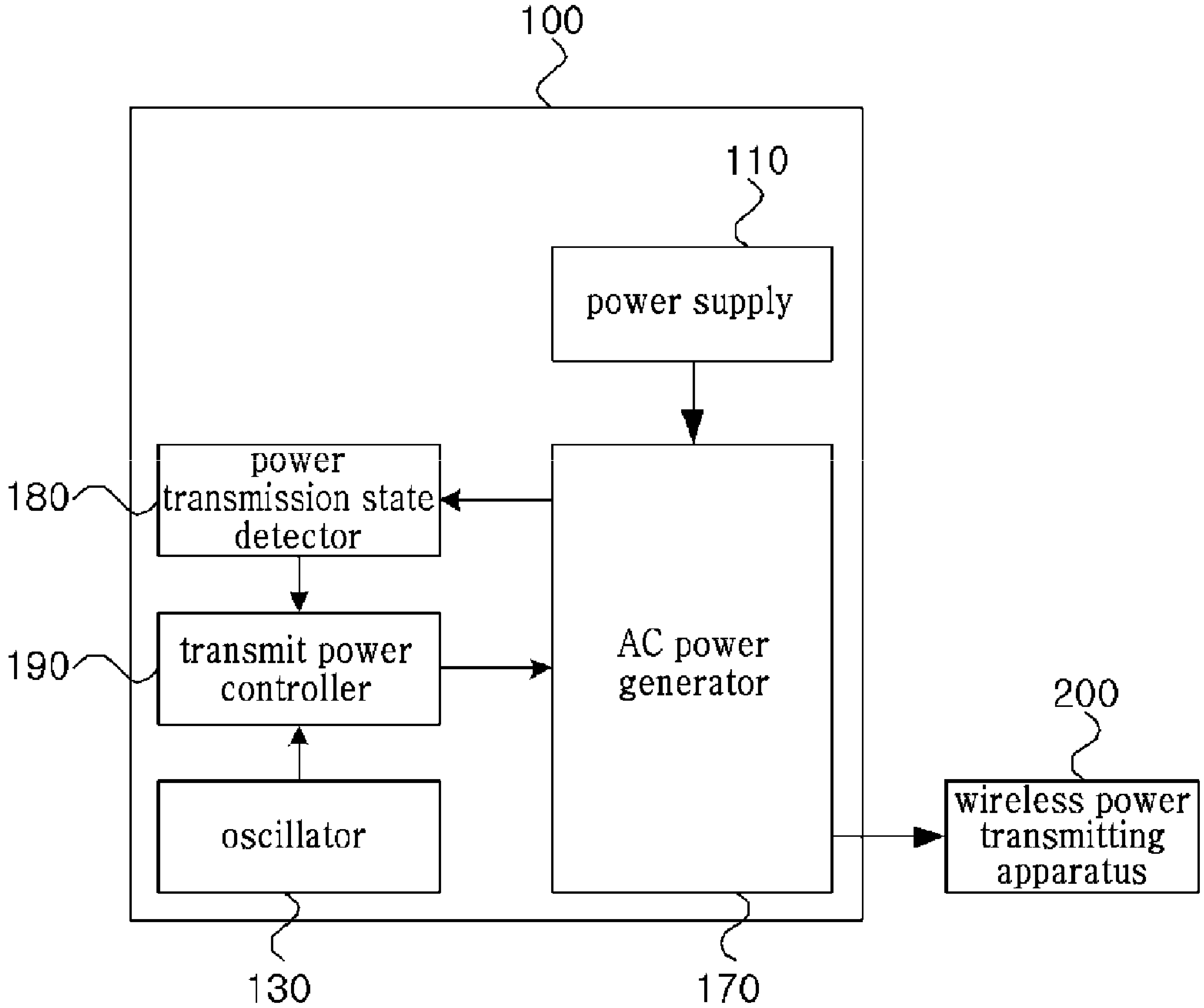

100
110
power supply
180
power transmission state detector
190
transmit power controller
oscillator
AC power generator
200
wireless power transmitting apparatus
130
170

FIG.17

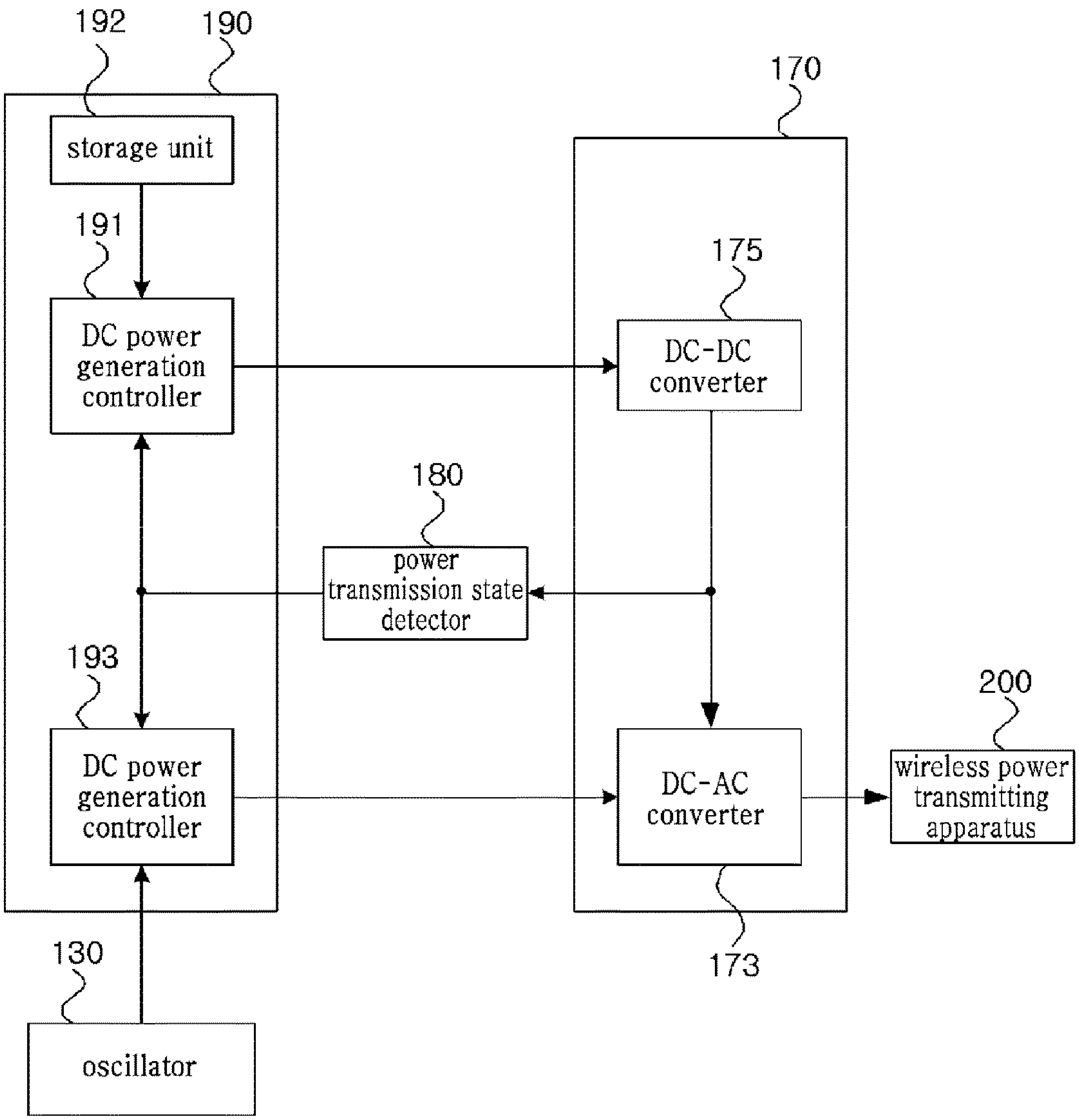

192
190
170
storage unit
191
175
DC power generation controller
DC-DC converter
180
power transmission state detector
193
200
DC power generation controller
DC-AC converter
wireless power transmitting apparatus
173
130
oscillator

FIG.18

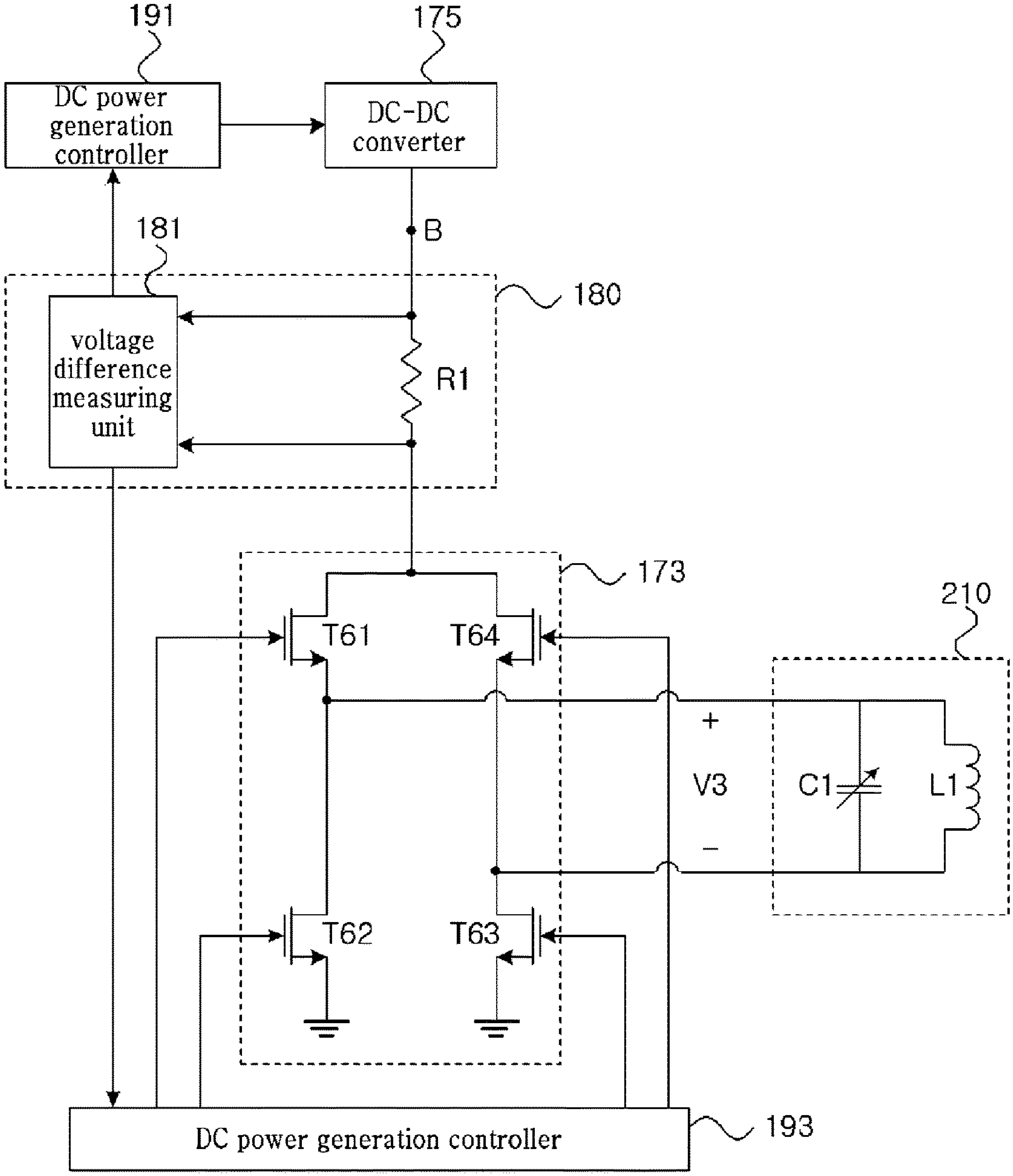
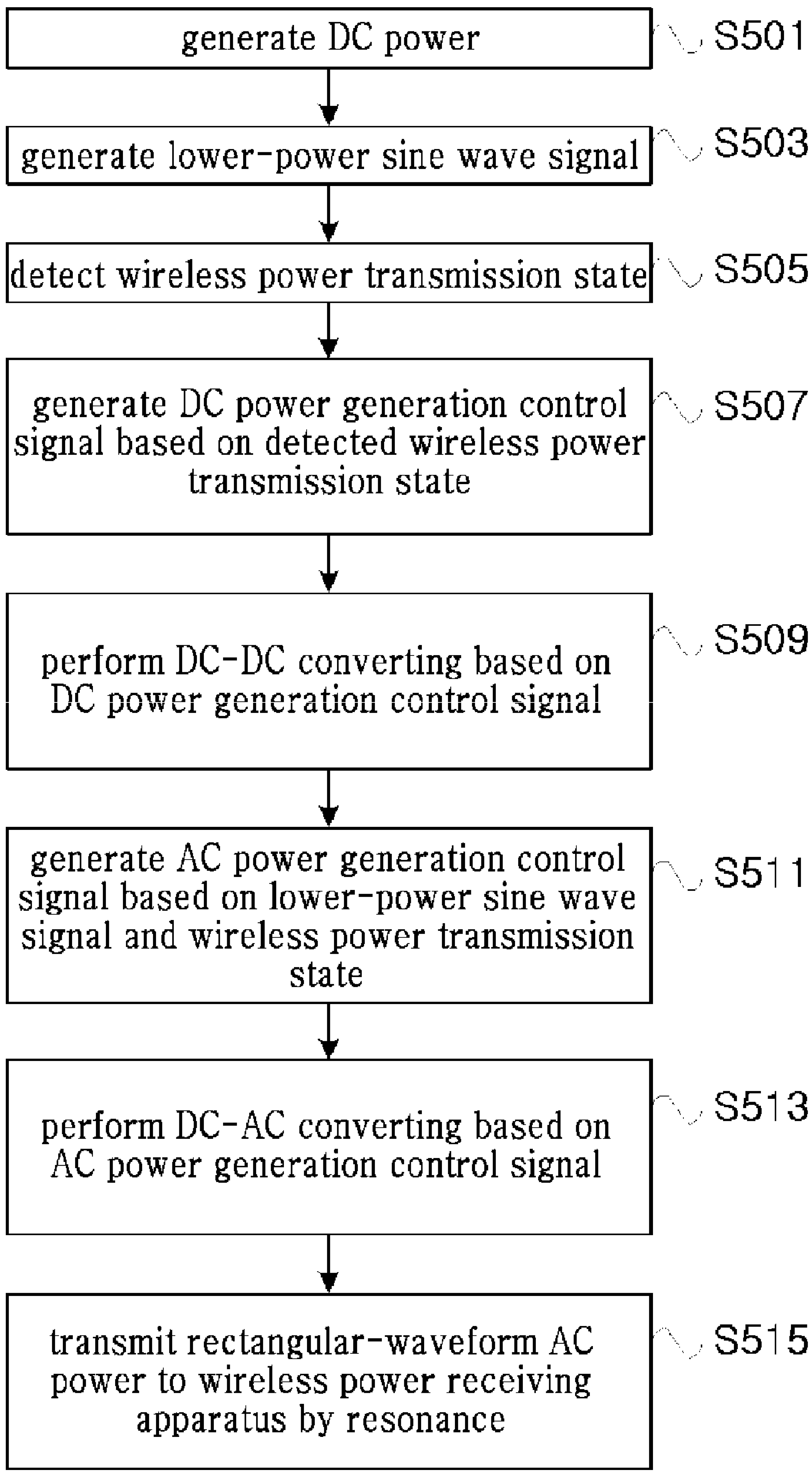

191
175
DC power generation controller
DC-DC converter
B
181
180
voltage difference measuring unit
R1
173
210
T61
T64
T62
T63
+
V3
−
C1
L1
DC power generation controller
193

FIG.19


generate DC power
S501
generate lower-power sine wave signal
S503
detect wireless power transmission state
S505
generate DC power generation control signal based on detected wireless power transmission state
S507
perform DC-DC converting based on DC power generation control signal
S509
generate AC power generation control signal based on lower-power sine wave signal and wireless power transmission state
S511
perform DC-AC converting based on AC power generation control signal
S513
transmit rectangular-waveform AC power to wireless power receiving apparatus by resonance
S515

WIRELESS POWER TRANSMITTING APPARATUS AND METHOD THEREOF

Matter enclosed in heavy brackets [ ] appears in the original patent but forms no part of this reissue specification; matter printed in italics indicates the additions made by reissue; a claim printed with strikethrough indicates that the claim was canceled, disclaimed, or held invalid by a prior post-patent action or proceeding.

CROSS-REFERENCE TO RELATED APPLICATIONS

[This application is a continuation of U.S. application Ser. No. 13/826,526, filed Mar. 14, 2013, which claims the benefit under 35 U.S.C. §119 of Korean Patent Application Nos. 10-2012-0027977, filed Mar. 19, 2012 and 10-2012-0146956, filed Dec. 14, 2012, which are hereby incorporated by reference in their entirety.**]** *This Application is a Continuation Reissue of U.S. patent application Ser. No. 16/510,270 filed on Jul. 12, 2019, which is a Reissue of U.S. application Ser. No. 14/980,904, issued as U.S. Pat. No. 9,711,974 on Jul. 18, 2017, which is a Continuation of U.S. patent application Ser. No. 13/826,526 filed on Mar. 14, 2013 (now U.S. Pat. No. 9,225,391 issued on Dec. 29, 2015), which claims the priority benefit under 35 U.S.C. § 119(a) to Korean Patent Application Nos. 10-2012-0146956 filed on Dec. 14, 2012 and 10-2012-0027977 filed on Mar. 19, 2012, both filed in the Republic of Korea, all of which are hereby expressly incorporated by reference into the present application. More than one Reissue Application has been filed for U.S. Pat. No. 9,711,974: the present application and U.S. patent application Ser. No. 16/510,270.*

BACKGROUND

The disclosure relates to a wireless power transmitting apparatus and a method thereof.

A wireless power transmission or a wireless energy transfer refers to a technology of wirelessly transferring electric energy to desired devices. In the 1800's, an electric motor or a transformer employing the principle of electromagnetic induction has been extensively used and then a method for transmitting electrical energy by irradiating electromagnetic waves, such as radio waves or lasers, has been suggested. Actually, electrical toothbrushes or electrical razors, which are frequently used in daily life, are charged based on the principle of electromagnetic induction. The electromagnetic induction refers to a phenomenon in which voltage is induced so that current flows when a magnetic field is varied around a conductor. Although the commercialization of the electromagnetic induction technology has been rapidly progressed around small-size devices, the power transmission distance is short.

Until now, wireless energy transmission schemes include a remote telecommunication technology based on magnetic resonance and a short wave radio frequency in addition to the electromagnetic induction.

Recently, among wireless power transmitting technologies, an energy transmitting scheme employing magnetic resonance has been widely used.

In a wireless power transmitting system employing magnetic resonance, since an electrical signal generated between the wireless power transmitting apparatus and the wireless power receiving apparatus is wirelessly transferred through coils, a user may easily charge electronic appliances such as a portable device.

A wireless power transmitting apparatus generates AC power having a resonance frequency to be transmitted to a wireless power receiving apparatus. In this case, power transmission efficiency is determined due to various factors. The demand for wireless power transmission efficiency is increased.

BRIEF SUMMARY

The disclosure provides a wireless power transmitting apparatus capable of improving wireless power transmission efficiency and a method thereof.

According to the embodiment, there is provided a wireless power transmitting apparatus wirelessly transmitting power to a wireless power receiving apparatus. The wireless power transmitting apparatus includes a detector detecting a wireless power transmission state between the wireless power transmitting apparatus and the wireless power receiving apparatus, a transmit power controller generating a control signal to control transmit power based on the detected wireless power transmission state, an AC power generator generating an AC power using first DC power based on the control signal, and a transmission induction coil unit transmitting the AC power to a transmission resonance coil through an electromagnetic induction scheme.

According to the embodiment, there is provided a wireless power transmitting apparatus wirelessly transmitting power to a wireless power receiving apparatus. The wireless power transmitting apparatus includes a transmission induction coil transmitting power applied thereto to a transmission resonance coil through an electromagnetic induction scheme, a transistor circuit unit having a full-bridge structure and connected to the transmission induction coil, a detector detecting a wireless power transmission state between the wireless power transmitting apparatus and the wireless power receiving apparatus, and a transmit power controller controlling the transistor circuit unit having the full-bridge structure based on the detected wireless power transmission state.

As described above, according to the embodiment, the efficiency of the wireless power transmitting apparatus can be increased.

In addition, according to the embodiment, circuits can be inhibited from being destroyed due to high current.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a view showing a wireless power system according to one embodiment.

FIG. **2** is a circuit diagram showing an equivalent circuit of the transmission induction coil unit according to the one embodiment.

FIG. **3** is a circuit diagram showing an equivalent circuit of a power supply device and a wireless power transmitting apparatus according to one embodiment.

FIG. **4** is a circuit diagram showing an equivalent circuit of a wireless power receiving apparatus according to one embodiment.

FIG. **5** is a block diagram showing the power supply device according to one embodiment.

FIG. **6** is a block diagram showing an AC power generator and a transmit power controller according to one embodiment.

FIG. **7** is a circuit diagram showing a DC-DC converter according to one embodiment.

FIG. **8** is a circuit diagram showing the DC-AC converter and the power transmission state detector according to one embodiment.

FIG. **9** is a flowchart showing a wireless power transmitting method according to one embodiment

FIG. **10** shows waveforms of voltage at each node in the power supply device according to one embodiment.

FIG. **11** is a block diagram showing a power supply device according to another embodiment.

FIG. **12** is a block diagram showing an AC power generator and a transmit power controller according to another embodiment.

FIG. **13** is a circuit diagram showing a DC-AC converter and a power transmission state detector according to another embodiment.

FIG. **14** is a flowchart showing a wireless power transmitting method according to another embodiment

FIG. **15** shows waveforms of voltage at each node in the power supply device according to another embodiment.

FIG. **16** is a block diagram showing a power supply device according to still another embodiment.

FIG. **17** is a block diagram showing an AC power generator and a transmit power controller according to still another embodiment.

FIG. **18** is a circuit diagram showing a DC-AC converter and a power transmission state detector according to still another embodiment.

FIG. **19** is a flowchart showing a wireless power transmitting method according to still another embodiment.

DETAILED DESCRIPTION

Hereinafter, embodiments will be described in detail with reference to accompanying drawings so that those skilled in the art can easily work with the embodiments. However, the embodiments may not be limited to those described below, but have various modifications. The elements, which are not concerned with the description of the embodiments in the drawings, may be omitted for the purpose of convenience or clarity. The same reference numbers will be assigned the same elements throughout the drawings.

In the following description, when a predetermined part "includes" a predetermined component, the predetermined part does not exclude other components, but may further include other components unless indicated otherwise.

Hereinafter, a wireless power transmitting system according to one embodiment will be described with reference to FIGS. **1** to **4**.

FIG. **1** is a view showing a wireless power system according to one embodiment.

Referring to FIG. **1**, the wireless power transmitting system may include a power supply device **100**, a wireless power transmitting apparatus **200**, a wireless power receiving apparatus **300** and a load **400**.

According to one embodiment, the power supply device **100** may be included in the wireless power transmitting apparatus **200**.

The wireless power transmitting apparatus **200** may include a transmission induction coil unit **210** and a transmission resonant coil unit **220**.

The wireless power receiving apparatus **300** may include a reception resonant coil unit **310**, a reception induction coil unit **320**, and a rectifying unit **330**.

Both terminals of the power supply device **100** are connected to both terminals of the transmission induction coil unit **210**.

The transmission resonant coil unit **220** may be spaced apart from the transmission induction coil unit **210** by a predetermined distance.

The reception resonant coil unit **310** may be spaced apart from the reception induction coil unit **320** by a predetermined distance.

Both terminals of the reception induction coil unit **320** are connected to both terminals of the rectifying unit **330**, and the load **400** is connected to both terminals of the rectifying unit **330**. According to one embodiment, the load **400** may be included in the wireless power receiving apparatus **300**.

The power generated from the power supply device **100** is transmitted to the wireless power transmitting apparatus **200**. The power received in the wireless power transmitting apparatus **200** is transmitted to the wireless power receiving apparatus **300** that makes resonance with the wireless power transmitting apparatus **200** due to a resonance phenomenon, that is, has the resonance frequency the same as that of the wireless power transmitting apparatus **200**.

Hereinafter, the power transmission process will be described in more detail.

The power supply device **100** generates AC power having a predetermined frequency and transmits the AC power to the wireless power transmitting apparatus **200**.

The transmission induction coil unit **210** and the transmission resonant coil unit **220** are inductively coupled with each other. In other words, if AC current flows through the transmission induction coil unit **210** due to the power received from the power supply apparatus **100**, the AC current is induced to the transmission resonant coil unit **220** physically spaced apart from the transmission induction coil unit **210** due to the electromagnetic induction.

Thereafter, the power received in the transmission resonant coil unit **220** is transmitted to the wireless power receiving apparatus **300**, which makes a resonance circuit with the wireless power transmitting apparatus **200**, through resonance.

Power can be transmitted between two LC circuits, which are impedance-matched with each other, through resonance. The power transmitted through the resonance can be farther transmitted with higher efficiency when comparing with the power transmitted by the electromagnetic induction.

The reception resonant coil unit **310** receives power from the transmission resonant coil unit **220** through the resonance. The AC current flows through the reception resonant coil unit **310** due to the received power. The power received in the reception resonant coil unit **310** is transmitted to the reception induction coil unit **320**, which is inductively coupled with the reception resonant coil unit **310**, due to the electromagnetic induction. The power received in the reception induction coil unit **320** is rectified by the rectifying unit **330** and transmitted to the load **400**.

According to one embodiment, the transmission induction coil unit **210**, the transmission resonant coil unit **220**, the reception resonant coil unit **310**, and the reception resonant coil unit **320** may have the shape of a circle, an oval, or a rectangle, but the embodiment is not limited thereto.

The transmission resonant coil unit **220** of the wireless power transmitting apparatus **200** may transmit power to the reception resonant coil unit **310** of the wireless power receiving apparatus **300** through a magnetic field.

In detail, the transmission resonant coil unit **220** and the reception resonant coil unit **310** are resonance-coupled with each other so that the transmission resonant coil unit **220** and the reception resonant coil unit **310** operate at a resonance frequency.

The resonance-coupling between the transmission resonant coil unit **220** and the reception resonant coil unit **310** can significantly improve the power transmission efficiency between the wireless power transmitting apparatus **200** and the wireless power receiving apparatus **300**.

A quality factor and a coupling coefficient are important in the wireless power transmission. In other words, the power transmission efficiency can be gradually improved as the values of the quality factor and the coupling coefficient are increased.

The quality factor may refer to an index of energy that may be stored in the vicinity of the wireless power transmitting apparatus **200** or the wireless power receiving apparatus **300**.

The quality factor may vary according to the operating frequency ω as well as a shape, a dimension and a material of a coil. The quality factor may be expressed as following equation, $Q=\omega*L/R$. In the above equation, L refers to the inductance of a coil and R refers to resistance corresponding to the quantity of power loss caused in the coil.

The quality factor may have a value of 0 to infinity The power transmission efficiency between the wireless power transmitting apparatus **200** and the wireless power receiving apparatus **300** can be improved as the value of the quality factor is increased.

The coupling coefficient represents the degree of magnetic coupling between a transmission coil and a reception coil, and has a value of 0 to 1.

The coupling coefficient may vary according to the relative position and the distance between the transmission coil and the reception coil.

FIG. **2** is a circuit diagram showing an equivalent circuit of the transmission induction coil unit **210** according to the one embodiment.

As shown in FIG. **2**, the transmission induction coil unit **210** may include an inductor L**1** and a capacitor C**1**, and a circuit having a desirable inductance and a desirable capacitance can be constructed by the inductor L**1** and the capacitor C**1**.

The transmission induction coil unit **210** may be constructed as an equivalent circuit in which both terminals of the inductor L**1** are connected to both terminals of the capacitor C**1**. In other words, the transmission induction coil unit **210** may be constructed as an equivalent circuit in which the inductor L**1** is connected to the capacitor C**1** in parallel.

The capacitor C**1** may include a variable capacitor, and impedance matching may be performed by adjusting the capacitance of the capacitor C**1**. The equivalent circuit of each of the transmission resonant coil unit **220**, the reception resonant coil unit **310** and the reception induction coil unit **320** may be the same as the equivalent circuit shown in FIG. **2**.

FIG. **3** is a circuit diagram showing an equivalent circuit of the power supply device **100** and the wireless power transmitting apparatus **200** according to one embodiment.

As shown in FIG. **3**, the transmission induction coil unit **210** includes the inductor L**1** having predetermined inductance and a capacitor C**1** having predetermined capacitance. The transmission resonant coil unit **220** includes an inductor L**2** having predetermined inductance and a capacitor C**2** having predetermined capacitance.

FIG. **4** is a circuit diagram showing an equivalent circuit of the wireless power receiving apparatus **300** according to one embodiment.

As shown in FIG. **4**, the reception resonant coil unit **310** includes an inductor L**3** having predetermined inductance and a capacitor C**1** having predetermined capacitance. The reception induction coil unit **320** includes an inductor L**4** having predetermined inductance and a capacitor C**4** having predetermined capacitance.

The rectifying unit **330** may transfer converted DC power to the load **400** by converting AC power received from the reception induction coil unit **320** into the DC power.

In detail, the rectifying unit **330** may include a rectifier and a smoothing circuit. According to one embodiment, the rectifier may include a silicon rectifier and may be equivalent as a diode D**1** as shown in FIG. **4**.

The rectifier may convert AC power received from the reception induction coil unit **320** into the DC power.

The smoothing circuit may output smooth DC power by removing AC components from the DC power converted by the rectifier. According to one embodiment, as shown in FIG. **4**, the smoothing circuit may include a rectifying capacitor C**5**, but the embodiment is not limited thereto.

The load **400** may be a predetermined rechargeable battery or a device requiring the DC power. For example, the load **400** may refer to a battery *340*.

The wireless power receiving apparatus **300** may be installed in an electronic device, such as a cellular phone, a laptop computer or a mouse, requiring the power. Accordingly, the reception resonant coil unit **310** and the reception induction coil unit **320** may have the shape suitable to the shape of the electronic device.

The wireless power transmitting apparatus **200** may interchange information with the wireless power receiving apparatus **300** through in-band communication or out-of-band communication.

The in-band communication refers to the communication for interchanging information between the wireless power transmitting apparatus **200** and the wireless power receiving apparatus **300** through a signal having the frequency used in the wireless power transmission. The wireless power receiving apparatus **300** may further include a switch, and may receive or may not receive power transmitted from the wireless power transmitting apparatus **200** through a switching operation of the switch. Accordingly, the wireless power transmitting apparatus **200** can recognize an on-signal or an off-signal of the switch included in the wireless power receiving apparatus **300** by detecting the quantity of power consumed in the wireless power transmitting apparatus **200**.

In detail, the wireless power receiving apparatus **300** may change the power consumed in the wireless power transmitting apparatus **200** by adjusting the quantity of power absorbed in a resistor by using the resistor *R11* and the switch *SW*. The wireless power transmitting apparatus **200** may acquire the state information of the wireless power receiving apparatus **300** by detecting the variation of the power consumption. The switch *SW* may be connected to the resistor *R11* in series. According to one embodiment, the state information of the wireless power receiving apparatus **300** may include information about the present charge quantity in the wireless power receiving apparatus **300** and the change of the charge quantity.

In more detail, if the switch is open, the power absorbed in the resistor becomes zero, and the power consumed in the wireless power transmitting apparatus **200** is reduced.

If the switch is short-circuited, the power absorbed in the resistor becomes greater than zero, and the power consumed in the wireless power transmitting apparatus **200** is increased. If the wireless power receiving apparatus repeats the above operation, the wireless power transmitting apparatus **200** detects power consumed therein to make digital communication with the wireless power receiving apparatus **300**.

The wireless power transmitting apparatus **200** receives the state information of the wireless power receiving apparatus **300** through the above operation so that the wireless power transmitting apparatus **200** can transmit appropriate power.

On the contrary, the wireless power transmitting apparatus **200** may include a resistor and a switch to transmit the state information of the wireless power transmitting apparatus **200** to the wireless power receiving apparatus **300**. According to one embodiment, the state information of the wireless power transmitting apparatus **200** may include information about the maximum quantity of power to be supplied from the wireless power transmitting apparatus **200**, the number of wireless power receiving apparatus **300** receiving the power from the wireless power transmitting apparatus **200** and the quantity of available power of the wireless power transmitting apparatus **200**.

Hereinafter, the out-of-band communication will be described

The out-of-band communication refers to the communication performed through a specific frequency band other than the resonance frequency band in order to interchange information necessary for the power transmission. The wireless power transmitting apparatus **200** and the wireless power receiving apparatus **300** can be equipped with out-of-band communication modules to interchange information necessary for the power transmission. The out-of-band communication module may be installed in the power supply device. In one embodiment, the out-of-band communication module may use a short-distance communication technology, such as Bluetooth, Zigbee, WLAN or NFC, but the embodiment is not limited thereto.

Hereinafter, the power supply device **100** according to one embodiment will be described with reference to FIGS. **5** to **10**.

FIG. **5** is a block diagram showing the power supply device **100** according to one embodiment.

As shown in FIG. **5**, the power supply device **100** according to one embodiment includes a power supply **110**, an oscillator **130**, an AC power generator **150**, a power transmission state detector **180**, and a transmit power controller **190**. In addition, the power supply device **100** is connected with the wireless power transmitting apparatus **200**.

The power supply **110** generates DC power having DC voltage and outputs the DC power through an output terminal thereof.

The oscillator **130** generates a lower-power sine wave signal.

The power transmission state detector **180** detects a wireless power transmission state between the wireless power transmitting apparatus **200** and the wireless power transmitting apparatus **300**.

The transmit power controller **190** generates a control signal to control the AC power generator **150** based on the detected wireless power transmission state.

The AC power generator **150** generates an AC power. At this time, the AC power can have various waveforms such as a rectangular-waveform, sinusoidal-waveform, or etc. In particular, the AC power generator **150** generates AC power having rectangular-waveform voltage by amplifying the lower-power sine wave signal of the oscillator **130** using DC power of the power supply **110** based on the control signal of the transmit power controller **190**.

The wireless power transmitting apparatus **200** transmits the output power of the AC power generator **150** to the wireless power receiving apparatus **300** by resonance.

FIG. **6** is a block diagram showing the AC power generator **150** and the transmit power controller **190** according to one embodiment.

As shown in FIG. **6**, the AC power generator **150** according to one embodiment includes AC power generation controller **151**, a DC-AC converter **153**, and a DC-DC converter **155**, and the transmit power controller **190** includes a DC power generation controller **191** and a storage unit **192**.

The AC power generation controller **151** generates an AC power generation control signal based on the lower-power sine wave signal of the oscillator **130**.

The DC power generation controller **191** generates a DC power generation control signal based on the detected wireless power transmission state so that the DC-DC converter **155** may output power having output current in a target current range and target DC voltage.

The storage unit **192** stores a look-up table.

The DC-DC converter **155** converts the output power of the power supply **110** into DC power, which has output current in the target current range and the target DC voltage, based on the DC power generation control signal.

The DC-AC converter **153** converts the output power of the DC-DC converter **155** into AC power having the rectangular-waveform AC voltage based on the AC power generation control signal, and outputs the power to the transmission induction coil unit **210**.

FIG. **7** is a circuit diagram showing the DC-DC converter **155** according to one embodiment.

As shown in FIG. **7**, the DC-DC converter **155** includes an inductor L**11**, a power switch T**11**, a diode DK and a capacitor C**11**. The power switch T**11** may be realized by using a transistor. In particular, the power switch T**11** may include an n-channel metal-oxide-semiconductor field-effect transistor (NMOSFET), but may be substituted with another device performing the same function.

One terminal of the inductor L**11** is connected with an output terminal of the power supply **110**, and an opposite terminal of the inductor L**11** is connected with a drain electrode of the power switch T**11**.

The gate electrode of the power switch T**11** is connected with an output terminal of the DC power generation controller **191**, and a source electrode of the power switch T**11** is connected with the ground.

An anode electrode of the diode D**11** is connected with the drain electrode of the power switch T**11**.

One terminal of the capacitor C**11** is connected with the cathode electrode of the diode DK and an opposite terminal of the capacitor C**11** is connected with the ground.

FIG. **8** is a circuit diagram showing the DC-AC converter **153** and the power transmission state detector **180** according to one embodiment.

As shown in FIG. **8**, the DC-AC converter **153** includes a transistor circuit unit having a half-bridge structure. The half-bridge transistor circuit includes an upper transistor T**21**, a lower transistor T**22**, and a DC cut-off capacitor C**21**, and is connected to the AC power generation controller **151** and the transmission induction coil unit **210**. The power transmission state detector **180** includes a resistor R**1** and a voltage difference measuring unit **181**, and is connected with the DC-DC converter **155**, the DC-AC converter **153**, and the DC power generation controller **191**. The DC-AC converter **153** is connected with the DC-DC converter **155** through the resistor R**1**. The upper and lower transistors T**21** and T**22** may include n-channel metal-oxide-semiconductor field-effect transistor (NMOS), but may be substituted with another device performing the same function.

The AC power generation controller **151** has an output terminal for an upper transistor control signal and an output terminal for a lower transistor control signal, and outputs the AC power generation control signal based on the lower-power sine wave signal. The AC power generation controller **151** generates the upper transistor control signal as the AC power generation control signal based on the lower-power sine wave signal of the oscillator **130**, and outputs the upper transistor control signal through the output terminal for the upper transistor control signal. The AC power generation controller **151** generates the lower transistor control signal as the AC power generation control signal based on the lower-power sine wave signal of the oscillator **130**, and outputs the lower transistor control signal through the output terminal for the lower transistor control signal.

A drain electrode of the upper transistor T**21** is connected with one terminal of the resistor R**1**, and the gate electrode is connected with the output terminal for the upper transistor control signal of the AC power generation controller **151**.

A drain electrode of the lower transistor T**22** is connected with a source electrode of the upper transistor T**21**, a gate electrode of the lower transistor T**22** is connected with the output terminal for the lower transistor control signal of the AC power generation controller **151**, and a source electrode of the lower transistor T**22** is connected with the ground.

One terminal of the DC cut-off capacitor C**21** is connected with the source electrode of the upper transistor T**21**, and an opposite terminal of the DC cut-off capacitor C**21** is connected with one terminal of the inductor L**1**. An opposite terminal of the inductor L**1** is connected with the ground.

The voltage difference measuring unit **181** measures the difference between voltages applied to both terminals of the resistor R**1**.

Hereinafter, a wireless power transmitting method according to one embodiment will be described with reference to FIGS. **9** and **10**.

FIG. **9** is a flowchart showing the wireless power transmitting method according to one embodiment, and FIG. **10** shows waveforms of voltage at each node in the power supply device **100** according to one embodiment.

In particular, FIG. **9** shows the wireless power transmitting method to explain the embodiments of FIGS. **6** to **8** in detail.

The power supply **110** generates DC power having DC voltage (step S**101**). In particular, the power supply **110** may convert AC power having AC voltage into the DC power having DC voltage.

The oscillator **130** generates the lower-power sine wave signal (step S**103**).

The power transmission state detector **180** detects the wireless power transmission state (step S**105**). The power transmission state detector **180** may detect the wireless power transmission state based on the level of the output current of the DC-DC converter **155**. Since the voltages applied to the both terminal of the resistor R**1** are proportional to the level of the output current of the DC-DC converter **155**, the voltage difference measuring unit **181** of the power transmission state detector **180** may detect the wireless power transmission state based on the different between the voltages applied to both terminals of the resistor R**1**.

Since the coupling coefficient varies depending on the distance between the wireless power transmitting apparatus **200** and the wireless power reception apparatus **300** or the relatively positions thereof, the wireless power transmission state may be changed. In other words, as the distance between the distance between the wireless power transmitting apparatus **200** and the wireless power reception apparatus **300** is increased, the coupling coefficient is reduced, so that the wireless power transmission state may be degraded. As the wireless power transmission state becomes degraded, even if the wireless power transmitting apparatus **200** transmits power having the same intensity to the wireless power receiving apparatus **300**, greater power is consumed due to the inferior transmission efficiency. Therefore, the power transmission state detector **180** may detect the wireless power transmission state based on the level of the output current of the DC-DC converter **155**.

Since the output current of the DC-DC converter **155** may not be constantly maintained, the power transmission state detector **180** may measure the peak-to-peak value of the output current of the DC-DC converter **155**.

The DC power generation controller **191** generates a DC power generation control signal based on the detected wireless power transmission state so that the DC-DC converter **155** may output DC power having output current in a target current range and target DC voltage (step S**107**), and outputs the DC power generation control signal to the gate electrode of the transistor T**11**. In this case, the target current range may have a constant value regardless of the level of the target DC voltage, or may vary depending on the level of the target DC voltage. In addition, the target current range may be the range of the peak-to-peak value of the target current. As shown in FIG. **10**, the DC power generation control signal may be a pulse width modulation (PWM) signal continuously represented throughout the whole duration. The DC power generation controller **191** may determine a duty ratio of the PWM signal based on the detected wireless power transmission state.

According to one embodiment, the voltage difference measuring unit **181** obtains a measurement output current value based on the difference between voltages applied to both terminals of the resistor R**1**. Thereafter, if the measurement output current value gets out of the reference range, the DC power generation controller **191** changes the duty rate, and outputs the DC power generation control signal serving as the PWM signal having the changed duty rate to the gate electrode of the transistor T**11** so that the output current value of the DC-DC converter **155** becomes in the reference range. In detail, if the measurement output current value is greater than the upper limit of the reference range, the DC power generation controller **191** reduces the duty rate and outputs the DC power generation control signal serving as the PWM signal having the reduced duty rate to the gate electrode of the transistor T**11** so that the output current value of the DC-DC converter **155** becomes in the reference range. Further, if the measurement output current value is smaller than the lower limit of the reference range, the DC power generation controller **191** increases the duty rate and outputs the DC power generation control signal serving as the PWM signal having the increased duty rate to the gate electrode of the transistor T**11** so that the output current value of the DC-DC converter **155** becomes in the reference range.

According to another embodiment, the storage unit **192** may have a look-up table representing the relationship between a plurality of measurement output power values and a plurality of target output voltage values. Table 1 shows the look-up table representing the relationship between the measurement output power values and the target output voltage values according to one embodiment.

TABLE 1

Measurement Output Power	Target Output Voltage
10 W or less	12 V
10~12 W	14 V
12~14 W	16 V
14~16 W	18 V
16~18 W	20 V
18~20 W	22 V
20 W or more	24

In this case, the voltage difference measuring unit **181** obtains a measurement output current value based on the difference between voltages applied to both terminals of the resistor R**1**. Thereafter, the DC power generation controller **191** obtains a measurement output power value of present output power of the DC-DC converter **155** based on the measurement output current value, and searches for a target output voltage value corresponding to the measurement output power value in the look-up table. Then, the duty rate of the PWM signal is determined using the voltage of the node B as feed-back information so that the output voltage of the DC-DC converter **155** may have the target output voltage value, and the DC power generation control signal may be generated based on the duty rate.

According to another embodiment, the storage unit **192** may have a look-up table representing the relationship between a plurality of measurement output current values and a plurality of target output voltage values. In this case, the voltage difference measuring unit **181** obtains a measurement output current value based on the difference between voltages applied to both terminals of the resistor R**1**. Thereafter, the DC power generation controller **191** searches for a target output voltage value corresponding to the measurement output current value in the look-up table. Then, the duty rate of the PWM signal is determined using the voltage of the node B as feed-back information so that the output voltage of the DC-DC converter **155** may have the target output voltage value, and the DC power generation control signal may be generated based on the duty rate.

Table 2 shows a look-up table according to one embodiment.

TABLE 2

Measurement output current at initial output voltage	Coupling coefficient	Target output voltage	Desirable current range
100 mA or less	0.03 or less	30 V	801~851 mA
101~150 mA	0.05	28 V	751~800 mA
151~200 mA	0.08	26 V	701~751 mA
201~250 mA	0.11	24 V	651~700 mA
251~300 mA	0.14	22 V	601~650 mA
301~350 mA	0.17	20 V	551~600 mA
351 mA or more	0.20 or more	18 V	501~550 mA

As shown in table 2, the storage unit **192** may have a look-up table corresponding to an output current value of the DC-DC converter **155**, a coupling coefficient, an output voltage value of the DC-DC converter **155**, and a desirable current range.

If the level of the output current of the DC-DC converter **155** is 100 mA or more when the DC-DC converter **155** outputs DC power having an initial output voltage value, the

wireless power receiving apparatus **300** may be regarded as being detected. The initial output voltage may be 12V which is given for the illustrative purpose.

If the level of the output current of the DC-DC converter **155** is 120 mA when the DC-DC converter **155** outputs the DC power having the initial output voltage value, the coupling coefficient between the transmission resonance coil unit **220** of the wireless power transmitting apparatus **200** and the reception resonance coil unit **310** of the wireless power receiving apparatus **300** corresponds to 0.05. In this case, the DC power generation controller **191** determines the wireless power receiving apparatus **300** as being apart from the wireless power transmitting apparatus **200** and controls the DC-DC converter **155** to have the output voltage of 28V.

Thereafter, when the level of the output voltage of the DC-DC converter **155** is maintained at 28V, the DC power generation controller **191** determines if the level of the output current of the DC-DC converter **155** is in a desirable current range of 751 mA to 800 mA.

If the level of the output current of the DC-DC converter **155** is out of the desirable current range, the DC power generation controller **191** controls the DC-DC converter **155** so that the level of the output voltage of the DC-DC converter **155** is the level (12V) of the initial output voltage. If the level of the output current of the DC-DC converter **155** is 180 mA, the controller **270** determines the wireless power transmitting apparatus **200** as being closer to the wireless power receiving apparatus **300** when comparing with the case that the level of the output current of the DC-DC converter **155** is 120 mA. Accordingly, the controller **270** controls the DC-DC converter **155** such that the level of the output voltage of the DC-DC converter **155** is 26V.

Although the above example has been described in that the distance between the wireless power transmitting apparatus **200** and the wireless power receiving apparatus **300** is related to the intensity of current, various wireless power states such as a direction in which the wireless power transmitting apparatus **200** and the wireless power receiving apparatus **300** are placed may be considered.

As described above, the wireless power transmitting apparatus **200** adjusts power transmitted to the wireless power receiving apparatus **300** based on the various wireless power transmission states such as the distance from the wireless power receiving apparatus **300** and the direction in which the wireless power receiving apparatus **300** is placed, thereby maximizing the power transmission efficiency, and presenting the power loss.

The DC-DC converter **155** converts the output power of the power supply **110** into the DC power having the output current in the target current range and the target DC voltage based on the DC power generation control signal (step S**109**). The level of the output voltage of the DC-DC converter **155** may be equal to that of the output voltage of the power supply **110**, or greater than or smaller than that of the output voltage of the power supply **110**.

The AC power generation controller **151** generates an AC power generation control signal based on the sin-wave lower power of the oscillator **130** (step S**111**). The AC power generation controller **151** may generate the upper transistor control signal serving as the AC power generation control signal based on the sin-wave lower power of the oscillator **130**, and may output the upper transistor control signal through the output terminal for the upper transistor control signal. The AC power generation controller **151** may generate the lower transistor control signal serving as the AC power generation control signal based on the sin-wave lower power of the oscillator **130**, and may output the lower transistor control signal through the output terminal for the lower transistor control signal.

Hereinafter, the upper and lower transistor control signals will be described with reference to FIG. **10**.

As shown in FIG. **10**, the upper and lower transistor control signals have the rectangular waveform.

One period of the upper transistor control signal sequentially includes a turn-on time slot of the upper transistor T**21** and a turn-off time slot of the upper transistor T**21**. The turn-on time slot of the upper transistor T**21** may correspond to one half period of the lower-power sine wave signal of the oscillator **130**, and the turn-off time slot of the upper transistor T**21** may correspond to the other half period of the lower-power sine wave signal.

One period of the lower transistor control signal sequentially includes a turn-on time slot of the lower transistor T**22** and a turn-off time slot of the lower transistor T**22**. The turn-on time slot of the lower transistor T**22** may correspond to one half period of the lower-power sine wave signal of the oscillator **130**, and the turn-off time slot of the lower transistor T**22** may correspond to the other half period of the lower-power sine wave signal.

The upper transistor control signal has a level to turn on the upper transistor T**21** during the turn-on time slot of the upper transistor T**21**. The level to turn on the upper transistor T**21** may be a high level.

During the turn-off time slot of the upper transistor T**21**, the upper transistor control signal has a level to turn off the upper transistor T**21**. The level to turn off the upper transistor T**21** may be a low level.

During the turn-on time slot of the lower transistor T**22**, the lower transistor control signal has a level to turn on the lower transistor T**22**. The level to turn on the lower transistor T**22** may be a high level.

During the turn-off time slot of the lower transistor T**22**, the lower transistor control signal has a level to turn off the lower transistor T**22**. The level to turn off the lower transistor T**22** may be a low level.

During the turn-on time slot of the upper transistor T**21**, the lower transistor control signal has the level to turn off the lower transistor T**22** during the turn-off time slot of the lower transistor T**22**.

During the turn-on time slot of the lower transistor T**22**, the lower transistor control signal has the level to turn off the lower transistor T**22** during the turn-off time slot of the upper transistor T**21**.

In order to inhibit a short circuit occurring by simultaneously turning on the upper and the lower transistors T**21** and T**22**, the upper and lower transistor control signals may have a dead time slot.

In order to output power of voltage provided in a rectangular waveform having the duty cycle of 50%, the turn-on time slot of the upper transistor T**21** has a duration corresponding to (50−a) % of one period (T), and the dead time slot of the upper transistor T**21** has the duration of a % of one period (T). The turn-off time slot of the upper transistor T**21** may have a duration corresponding to 50% of one period (T), the turn-on time slot of the lower transistor T**22** may have a duration corresponding to (50−a) % of one period (T), the dead time slot of the lower transistor T**22** may have a duration corresponding to a % of one period (T), and the turn-off time slot of the lower transistor T**22** may have a duration corresponding to 50% of one period (T). For example, "a" may be 1%.

The DC-AC converter **153** converts the output power of the DC-DC converter **155** into AC power having rectangular-waveform AC voltage based on the AC power generation control signal (step S**113**) and outputs the AC power to the transmission induction coil unit **210**. Hereinafter, the operation of the DC-AC converter **153** will be described with reference to FIG. **10**.

The upper and lower transistors T**21** and T**22** output rectangular-waveform power having rectangular-waveform voltage V**3** shown in FIG. **10** according to the upper and lower transistor control signals having the dead time slot.

The DC cut-off capacitor C**21** cuts off DC voltage of the rectangular-waveform power and outputs the rectangular-waveform power having the rectangular-waveform AC voltage V**4** to the transmission induction coil unit **210**.

The wireless power transmitting apparatus **200** transmits the rectangular-waveform AC power having the rectangular-waveform AC voltage to the wireless power receiving apparatus **300** by resonance (step S**115**).

Hereinafter, a power supply device **100** according to another embodiment will be described with reference to FIGS. **11** to **15**.

FIG. **11** is a block diagram showing the power supply device **100** according to another embodiment.

As shown in FIG. **11**, the power supply device **100** according to another embodiment includes the power supply **110**, the oscillator **130**, an AC power generator **160**, the power transmission state detector **180**, and the transmit power controller **190**. In addition, the power supply device **100** is connected with the wireless power transmitting apparatus **200**.

The power supply **110** generates DC power having DC voltage and outputs the DC power through an output terminal thereof.

The oscillator **130** generates a lower-power sine wave signal.

The power transmission state detector **180** detects the wireless power transmission state.

The transmit power controller **190** generates a control signal to control the AC power generator **160** based on the detected wireless power transmission state and the lower-power sine wave signal of the oscillator **130**.

The AC power generator **160** generates AC power having rectangular-waveform voltage by amplifying the lower-power sine wave signal of the oscillator **130** using DC power of the power supply **110** based on the control signal of the transmit power controller **190**.

The wireless power transmitting apparatus **200** transmits the output power of the AC power generator **160** to the wireless power receiving apparatus **300** by resonance.

FIG. **12** is a block diagram showing the AC power generator **160** and the transmit power controller **190** according to another embodiment.

As shown in FIG. **12**, the AC power generator **160** according to another embodiment includes a DC-AC converter **163**, and the transmit power controller **190** includes an AC power generation controller **193**.

The AC power generation controller **193** generates an AC power generation control signal based on the lower-power sine wave signal of the oscillator **130**. In addition, the AC power generation controller **193** may generate the AC power generation control signal, which allows the power supply **110** to output DC power having output current in a target current range, based on the detected wireless power transmission state. The target current range may be the range of the peak-to-peak value of the target current.

The DC-AC converter **163** converts the output power of the power supply **110** into AC power having rectangular-waveform AC voltage based on the AC power generation control signal, and outputs the AC power to the transmission induction coil unit **210**.

FIG. **13** is a circuit diagram showing the DC-AC converter **163** and the power transmission state detector **180**.

As shown in FIG. **13**, the DC-AC converter **163** includes a full-bridge transistor circuit unit. The full-bridge transistor circuit unit includes two half-bridge transistor circuits. One of the two half-bridge transistor circuits includes upper and lower transistors T**41** and T**42**, and the other includes upper and lower transistors T**44** and T**43**. The upper transistors T**41** and T**44**, and the lower transistors T**42** and T**43** may be n-channel metal-oxide-semiconductor field-effect transistors (NMOS-FETs), and may be substituted with different devices performing the same operation.

The power transmission state detector **180** includes a resistor R**1** and the voltage difference measuring unit **181**, and is connected to the power supply **110**, the DC-AC converter **163**, and the AC power generation controller **193**. The DC-AC converter **163** is connected to the power supply **110** through the resistor R**1**.

The AC power generation controller **193** has first and second upper transistor control signal output terminals and first and second lower transistor control signal output terminals, and generates an AC power generation control signal based on the lower-power sine wave signal of the oscillator **130** and a wireless power transmission state.

A drain electrode of the upper transistor T**41** is connected with one terminal of the resistor R**1**, a gate electrode of the upper transistor T**41** is connected with the first upper transistor control signal output terminal of the AC power generation controller **193**, and a source electrode of the upper transistor T**41** is connected with one terminal of the inductor L**1**.

A drain electrode of the lower transistor T**42** is connected with the source electrode of the upper transistor T**41**, a gate electrode of the lower transistor T**42** is connected to the first lower transistor control signal output terminal of the AC power generation controller **193**, and a source electrode of the lower transistor T**42** is connected with the ground.

A drain electrode of the upper transistor T**44** is connected with one terminal of the resistor R**1**, a gate electrode of the upper transistor T**44** is connected with the second upper transistor control signal output terminal of the AC power generation controller **193**, and a source electrode of the upper transistor T**44** is connected with an opposite terminal of the inductor L**1**.

A drain electrode of the lower transistor T**43** is connected with the source electrode of the upper transistor T**44**, a gate electrode of the lower transistor T**43** is connected to the second lower transistor control signal output terminal of the AC power generation controller **193**, and a source electrode of the lower transistor T**43** is connected with the ground.

The voltage difference measuring unit **181** measures the difference between voltages applied to both terminals of the resistor R**1**.

Hereinafter, a wireless power transmitting method will be described with reference to FIGS. **14** and **15** according to another embodiment.

FIG. **14** is a flowchart showing the wireless power transmitting method according to another embodiment, and FIG. **15** shows waveforms of voltage at each node in the power supply device **100** according to another embodiment.

In particular, FIG. **14** shows the wireless power transmitting method to explain the embodiments of FIGS. **11** to **13** in detail.

The power supply **110** generates DC power having DC voltage (step S**301**). In particular, the power supply **110** may convert AC power having AC voltage into the DC power having DC voltage.

The oscillator **130** generates a lower-power sine wave signal (step S**303**).

The power transmission state detector **180** detects the wireless power transmission state (step S**305**). The power transmission state detector **180** may detect the wireless power transmission state based on the level of the output current of the power supply HO. Since the voltages applied to the both terminal of the resistor R**1** are proportional to the level of the output current of the power supply **110**, the voltage difference measuring unit **181** of the power transmission state detector **180** may detect the wireless power transmission state based on the different between the voltages applied to both terminals of the resistor R**1**. Since the output current of the power supply **110** may not be constantly maintained, the power transmission state detector **180** may measure the wireless power transmission state based on the peak-to-peak level of the output current of the power supply **110**.

The AC power generation controller **193** generates the AC power generation control signal allowing the power supply **110** to output DC power having the output current in the target current range, based on the detected wireless power transmission state (step S**311**), and outputs the generates the AC power generation control signal to the DC-AC converter **163**. Since the output current of the power supply **110** may not be constantly maintained, the power transmission state detector **180** may measure the peak-to-peak level of the output current of the power supply **110**.

According to one embodiment, the AC power generation controller **193** may determine an operating mode of the DC-AC converter **163** based on the detected wireless power transmission state, and may output the AC power generation control signal for the operating mode to the DC-AC converter **163**. In this case, the operating mode may be one of a full-bridge operating mode and a half-bridge operating mode. The voltage difference measuring unit **181** obtains a measurement output current value based on the difference between voltages applied to both terminals of the resistor R**1**. The DC power generation controller **191** may compare the measurement output current value with a reference value and determine the operating mode of the DC-AC converter **163** according to the comparison result. In this case, the reference value may be in the desirable current range of table 2 set according to the initial output voltage values. If the measurement output current value is greater than the reference value, the DC power generation controller **191** may determine the operating mode of the DC-AC converter **163** as the full-bridge operating mode. If the measurement output current value is smaller than the reference value, the DC power generation controller **191** may determine the operating mode of the DC-AC converter **163** as the half-bridge operating mode.

At the half-bridge operating mode, the AC power generation controller **193** operates one of two half-bridge transistor circuits, and stops the operation of the other. The AC power generation controller **193** turns off the upper transistor of the half-bridge transistor circuit, the operation of which is stopped, and turns on the lower transistor of the half-bridge transistor circuit. The AC power generation controller **193** applies a control signal to the half-bridge transistor circuit, the operation of which is allowed, as described with reference to FIG. **10**.

At the full-bridge operating mode, the AC power generation controller **193** alternately applies a control signal for one half period and a control signal for the other half period to the DC-AC converter **163**. During one half period, the upper transistor T**41** of one half-bridge transistor circuit is turned on, and the lower transistor T**42** thereof is turned off. The upper transistor T**44** of the other half-bridge transistor circuit is turned off, and the lower transistor T**43** thereof is turned on. During the other half period, the upper transistor T**41** of one half-bridge transistor circuit is turned off, and the lower transistor T**42** thereof is turned on. The upper transistor T**44** of the other half-bridge transistor circuit is turned on, and the lower transistor T**43** thereof is turned off. Two transistor operating modes may be synchronized with a lower-power sine wave signal of the oscillator **130**. In order to inhibit a short circuit occurring by simultaneously turning on the upper and the lower transistors, the upper and lower transistor control signals may have a dead time slot.

According to another embodiment, the voltage difference measuring unit **181** may obtain the measurement output current value based on the difference between voltages applied to both terminals of the resistor R**1**, the DC power generation controller **191** may obtain a measurement output power value, which is a present output power value of the power supply **110**, based on the measurement output current value, and may determine the operating mode of the DC-AC converter **163** based on the measurement output power value. In this case, the operating mode may be one of the full-bridge operating mode and the half-bridge operating mode. The DC power generation controller **191** may compare the measurement output power value with the reference value and determine the operating mode of the DC-AC converter **163** according to the comparison result. In this case, the reference value may be in the desirable current range of table 2 set according to the initial output voltage value. If the measurement output power value is greater than the reference value, the DC power generation controller **191** may determine the operating mode of the DC-AC converter **163** as a full-bridge operating mode. If the measurement output power value is smaller than the reference value, the DC power generation controller **191** may determine the operating mode of the DC-AC converter **163** as the half-bridge operating mode.

The DC-AC converter **163** converts the output power of the power supply **110** into the AC power having the rectangular-waveform AC voltage V**3** based on the AC power generation control signal (step S**313**), and outputs the output power to the transmission induction coil unit **210**.

The wireless power transmitting apparatus **200** transmits the rectangular-waveform AC power having the rectangular-waveform AC voltage V**3** to the wireless power receiving apparatus **300** by resonance (step S**315**).

Hereinafter, a power supply device **100** according to still another embodiment will be described with reference to FIGS. **16** to **19**.

FIG. **16** is a block diagram showing the power supply device **100** according to still another embodiment.

As shown in FIG. **16**, the power supply device **100** according to still another embodiment includes a power supply **110**, an oscillator **130**, an AC power generator **170**, a power transmission state detector **180**, and a transmit power controller **190**. In addition, the power supply device **100** is connected with the wireless power transmitting apparatus **200**.

The power supply **110** generates DC power having DC voltage and outputs the DC power through an output terminal thereof.

The oscillator **130** generates a lower-power sine wave signal.

The power transmission state detector **180** detects the wireless power transmission state.

The transmit power controller **190** generates a control signal to control the AC power generator **170** based on the detected wireless power transmission state and the lower-power sine wave signal of the oscillator **130**.

The AC power generator **170** generates AC power having rectangular-waveform voltage by amplifying the lower-power sine wave signal of the oscillator **130** using DC power of the power supply **110** according to the control signal of the transmit power controller **190**.

The wireless power transmitting apparatus **200** transmits the output power of the AC power generator **170** to the wireless power receiving apparatus **300** by resonance.

FIG. **17** is a block diagram showing the AC power generator **170** and the transmit power controller **190** according to still another embodiment.

As shown in FIG. **17**, the AC power generator **170** according to still another embodiment includes a DC-DC converter **175** and a DC-AC converter **173**, and the transmit power controller **190** includes an DC power generation controller **191**, a storage unit **192**, and an AC power generation controller **193**.

The DC power generation controller **191** generates a DC power generation control signal based on the detected wireless power transmission state so that the DC-DC converter **175** may output DC power having output current in a target current range and target DC voltage.

The storage unit **192** stores a look-up table.

The DC-DC converter **175** converts the output power of the power supply **110** into the DC power, which has output current in the target current range and the target DC voltage, based on the DC power generation control signal.

The AC power generation controller **193** generates an AC power generation control signal based on the lower-power sine wave signal of the oscillator **130**. In addition, the AC power generation controller **193** may generate the AC power generation control signal, which allows the DC-DC converter **175** to output DC power having the output current in the target current range, based on the detected wireless power transmission state. The target current range may be the range of the peak-to-peak value of the target current.

The DC-AC converter **173** converts the output power of the DC-DC converter **155** into the rectangular-waveform power based on the AC power generation control signal, and outputs the power to the transmission induction coil unit **210**.

FIG. **18** is a circuit diagram showing the DC-AC converter **173** and the power transmission state detector **180** according to still another embodiment.

As shown in FIG. **18**, the DC-AC converter **173** includes a full-bridge transistor circuit unit. The full-bridge transistor circuit unit includes two half-bridge transistor circuits. One of the two half-bridge transistor circuits includes upper and lower transistors T**61** and T**62**, and the other includes upper and lower transistors T**64** and T**63**. The upper transistors T**61** and T**64**, and the lower transistors T**62** and T**63** may be n-channel metal-oxide-semiconductor field-effect transistors (NMOS-FETs), and may be substituted with different devices performing the same operation.

The power transmission state detector **180** includes a resistor R**1** and the voltage difference measuring unit **181**, and is connected to the DC-DC converter **175**, the DC-AC converter **173**, and the AC power generation controller **193**.

The DC-AC converter **173** is connected to the DC-DC converter **175** through the resistor R**1**.

The AC power generation controller **193** has first and second upper transistor control signal output terminals and first and second lower transistor control signal output terminals, and generates an AC power generation control signal based on the lower-power sine wave signal of the oscillator **130** and a wireless power transmission state.

A drain electrode of the upper transistor T**61** is connected with one terminal of the resistor R**1**, a gate electrode of the upper transistor T**61** is connected with the first upper transistor control signal output terminal of the AC power generation controller **193**, and a source electrode of the upper transistor T**61** is connected with one terminal of the inductor L**1**.

A drain electrode of the lower transistor T**62** is connected with the source electrode of the upper transistor T**61**, a gate electrode of the lower transistor T**62** is connected to the first lower transistor control signal output terminal of the AC power generation controller **193**, and a source electrode of the lower transistor T**62** is connected with the ground.

A drain electrode of the upper transistor T**64** is connected with one terminal of the resistor R**1**, a gate electrode of the upper transistor T**64** is connected with the second upper transistor control signal output terminal of the AC power generation controller **193**, and a source electrode of the upper transistor T**64** is connected with an opposite terminal of the inductor L**1**.

A drain electrode of the lower transistor T**63** is connected with the source electrode of the upper transistor T**64**, a gate electrode of the lower transistor T**63** is connected to the second lower transistor control signal output terminal of the AC power generation controller **193**, and a source electrode of the lower transistor T**63** is connected with the ground.

The voltage difference measuring unit **181** measures the difference between voltages applied to both terminals of the resistor R**1**.

Hereinafter, a wireless power transmitting method will be described with reference to FIG. **19** according to still another embodiment.

FIG. **19** is a flowchart showing the wireless power transmitting method according to still another embodiment.

In particular, FIG. **19** shows the wireless power transmitting method to explain the embodiments of FIGS. **16** to **18** in detail.

The power supply **110** generates DC power having DC voltage (step S**501**). In particular, the power supply **110** may convert AC power having AC voltage into the DC power having DC voltage.

The oscillator **130** generates the lower-power sine wave signal (step S**503**).

The power transmission state detector **180** detects the wireless power transmission state (step S**505**). The power transmission state detector **180** may detect the wireless power transmission state based on the level of the output current of the DC-DC converter **175**. Since the voltages applied to the both terminal of the resistor R**1** are proportional to the level of the output current of the power supply **110**, the voltage difference measuring unit **181** of the power transmission state detector **180** may detect the wireless power transmission state based on the different between the voltages applied to both terminals of the resistor R**1**. Since the output current of the DC-DC converter **175** may not be constantly maintained, the power transmission state detector **180** may measure the peak-to-peak value of the output current of the DC-DC converter **175**.

The DC power generation controller **191** generates a DC power generation control signal based on the detected wireless power transmission state so that the DC-DC converter **175** may output DC power having current in the target current range and target DC voltage (step S**507**), and outputs the DC power generation control signal to the gate electrode of the transistor T**11**. Details of step S**507** have already been described in step S**107**.

The DC-DC converter **175** converts the output power of the power supply **110** into DC power having the output current in the target current range and the target DC voltage based on the DC power generation control signal (step S**509**).

The AC power generation controller **193** generates the AC power generation control signal allowing the DC-DC converter **175** to output DC power having the output current in the target current range, based on the detected wireless power transmission state (step S**511**), and outputs the AC power generation control signal to the DC-AC converter **173**. Details of step S**511** have already been described in step S**311**.

The DC-AC converter **173** converts the output power of the power supply **110** into the AC power having the rectangular-waveform AC voltage V**3** based on the AC power generation control signal (step S**513**), and outputs the output power to the transmission induction coil unit **210**.

The wireless power transmitting apparatus **200** transmits the rectangular-waveform AC power having the rectangular-waveform AC voltage V**3** to the wireless power receiving apparatus **300** by resonance (step S**515**).

Any reference in this specification to "one embodiment," "an embodiment," "example embodiment," etc., means that a particular feature, structure, or characteristic described in connection with the embodiment is included in at least one embodiment of the invention. The appearances of such phrases in various places in the specification are not necessarily all referring to the same embodiment. Further, when a particular feature, structure, or characteristic is described in connection with any embodiment, it is submitted that it is within the purview of one skilled in the art to effect such feature, structure, or characteristic in connection with other ones of the embodiments.

Although embodiments have been described with reference to a number of illustrative embodiments thereof, it should be understood that numerous other modifications and embodiments can be devised by those skilled in the art that will fall within the spirit and scope of the principles of this disclosure. More particularly, various variations and modifications are possible in the component parts and/or arrangements of the subject combination arrangement within the scope of the disclosure, the drawings and the appended claims. In addition to variations and modifications in the component parts and/or arrangements, alternative uses will also be apparent to those skilled in the art.

What is claimed is:

[1. A wireless power transmitting apparatus wirelessly transmitting power to a wireless power receiving apparatus, the wireless power transmitting apparatus comprising:

a detector detecting a wireless power transmission state between the wireless power transmitting apparatus and the wireless power receiving apparatus;

a transmit power controller generating a control signal to control transmit power based on the detected wireless power transmission state;

an AC power generator generating an AC power using a first DC power, wherein the generated AC power is determined based on the control signal; and a transmission coil unit transmitting the AC power to the wireless power receiving apparatus;

wherein the AC power generator comprises:

a DC-DC converter converting the first DC power into a second DC power, wherein the second DC power is determined based on the control signal; and

a DC-AC converter converting the second DC power into the AC power;

wherein the detector detects the wireless power transmission state based on a level of an output current of the DC-DC converter, and

wherein the detector detects the wireless power transmission state based on a peak-to-peak level of the output current of the DC-DC converter.]

[2. The wireless power transmitting apparatus of claim **1**, wherein the transmit power controller comprises a DC power generation controller generating a DC power generation control signal based on the detected wireless power transmission state, and

wherein the second DC power is determined based on the DC power generation control signal.]

[3. The wireless power transmitting apparatus of claim **2**, wherein the DC power generation controller changes a duty cycle of the DC power generation control signal based on the detected wireless power transmission state.]

[4. The wireless power transmitting apparatus of claim **1**, wherein the DC-AC converter comprises a transistor circuit unit including a half-bridge structure.]

[5. The wireless power transmitting apparatus of claim **1**, wherein the AC power generator comprises a full-bridge transistor circuit unit capable of operating at a half-bridge operating mode and a full-bridge operating mode,

wherein the transmit power controller comprises an AC power generation controller selecting one of the half-bridge operating mode or the full-bridge operating mode based on the detected wireless power transmission state, and generating an AC power generation control signal corresponding to the selected operating mode, and

wherein the full-bridge transistor circuit unit converts the second DC power into the AC power based on the AC power generation control signal.]

[6. The wireless power transmitting apparatus of claim **5**, wherein the full-bridge transistor circuit unit comprises:

a first transistor comprising a drain electrode having DC power applied thereto and a source electrode connected to one terminal of the transmission coil unit;

a second transistor comprising a drain electrode connected to the source electrode of the first transistor and a source electrode connected to a ground;

a third transistor comprising a drain electrode having the DC power applied thereto and a source electrode connected to an opposite terminal of the transmission coil unit; and

a fourth transistor comprising a drain electrode connected to the source electrode of the third transistor and a source electrode connected to the ground.]

[7. The wireless power transmitting apparatus of claim **6**, wherein, in the half-bridge operating mode, the transmit power controller turns off the third transistor, turns on the fourth transistor, turns on the first transistor, turns off the second transistor during one half period, and turns off the first transistor and turns on the second transistor during a remaining half period.]

[8. The wireless power transmitting apparatus of claim **6**, wherein, in the full-bridge operating mode, the transmit power controller turns on the first and fourth transistors and turns off the second and third transistors during one half period, and turns off the first and fourth transistors and turns on the second and third transistors during a remaining half period.]

[9. The wireless power transmitting apparatus of claim **1**, wherein the AC power is a rectangular-waveform power.]

10. A method of controlling a wireless power transmitter, the method comprising:

providing a DC power to an AC power generator;

generating, via the AC power generator, an AC power signal having a predetermined frequency to transmit wireless power;

transmitting state information of the wireless power transmitter using the predetermined frequency, the state information of the wireless power transmitter including a maximum power of the wireless power transmitter to be supplied from the wireless power transmitter and an available power of the wireless power transmitter;

detecting a variation of consumption of the wireless power;

in response to the variation being less than a reference value, transmitting, by the AC power generator, the wireless power to have a first waveform; and

in response to the variation being equal to or greater than the reference value, transmitting, by the AC power generator, the wireless power to have a second waveform different from the first waveform,

wherein the generating the AC power comprises:

converting, via a DC-DC converter included in the AC power generator, a first DC power into a second DC power determined based on a control signal; and

converting, via a DC-AC converter included in the AC power generator, the second DC power into the wireless power, and

wherein the detecting the variation of the consumption of the wireless power comprises detecting the variation based on a level of an output current of the DC-DC converter and based on an adjustment of a switch and a resistor included in a wireless power receiver consuming the transmitted wireless power.

11. The method of claim 10, wherein the AC power generator includes a full bridge transistor circuit for operating in a full bridge mode or a half bridge mode.

12. The method of claim 11, wherein the AC power generator operates in the half bridge mode for transmitting the first waveform.

13. The method of claim 12, wherein the AC power generator operates in the full bridge mode for transmitting the second waveform.

14. The method of claim 11, wherein the full bridge transistor circuit includes a first half bridge circuit and a second half bridge circuit.

15. The method of claim 14, wherein the AC power generator includes a controller operating the first half bridge circuit and stopping operation of the second half bridge circuit in the half bridge mode.

16. The method of claim 15, wherein the controller operates the first half bridge circuit and the second half bridge circuit in the full bridge mode.

17. The method of claim 10, wherein the detecting the variation of consumption of the wireless power comprises detecting a power consumption of the wireless power based on the switch being opened or closed and in series with the resistor, and *wherein the power consumption is increased when the switch is closed and decreased when the switch is opened.*

18. The method of claim 10, further comprising:

determining state information of the wireless power receiver including a change of a charge quantity of the wireless power.

19. The method of claim 18, wherein the AC power has the first waveform or the second waveform different than the first waveform based on the state information of the wireless power receiver.

20. A wireless power transmitter wireless transmitting power to a wireless power receiver, the wireless power transmitter comprising:

an AC power generator configured to generate an AC power signal having a predetermined frequency to transmit wireless power;

a detector configured to detect a variation of consumption of the wireless power; and

a controller configured to:

control the AC power generator to transmit state information of the wireless power transmitter using the predetermined frequency, the state information of the wireless power transmitter including a maximum power of the wireless power transmitter to be supplied from the wireless power transmitter and an available power of the wireless power transmitter;

in response to the variation being less than a reference value, control a transistor circuit of the AC power generator to transmit the wireless power to have a first waveform; and

in response to the variation being equal to or greater than the reference value, control the transistor circuit of the AC power generator to transmit the wireless power to have a second waveform different from the first waveform,

wherein the AC power generator comprises:

a DC-DC converter configured to convert a first DC power into a second DC power determined based on a control signal; and

a DC-AC converter configured to convert the second DC power into the wireless power, and

wherein the detector detects the variation of consumption of the wireless power based on a level of an output current of the DC-DC converter and based on an adjustment of a switch and a resistor included in a wireless power receiver consuming the transmitted wireless power.

21. The wireless power transmitter of claim 20, wherein the AC power generator includes a full bridge transistor circuit for operating in a full bridge mode or a half bridge mode.

22. The wireless power transmitter of claim 21, wherein the AC power generator operates in the half bridge mode for transmitting the first waveform.

23. The wireless power transmitter of claim 22, wherein the AC power generator operates in the full bridge mode for transmitting the second waveform.

24. The wireless power transmitter of claim 21, wherein the full bridge transistor circuit includes a first half bridge circuit and a second half bridge circuit.

25. The wireless power transmitter of claim 24, wherein the controller operates the first half bridge circuit and stops operation of the second half bridge circuit in the half bridge mode.

26. The wireless power transmitter of claim 25, wherein the controller operates the first half bridge circuit and the second half bridge circuit in the full bridge mode.

27. The wireless power transmitter of claim 20, wherein the controller detects the variation of consumption of the wireless power by detecting a power consumption of the wireless power based on the switch being opened or closed and in series with the resistor, and

wherein the power consumption is increased when the switch is closed and decreased when the switch is opened.

28. The wireless power transmitter of claim 20, wherein the controller is further configured to:

determine state information of the wireless power receiver including a change of a charge quantity of the wireless power.

29. The wireless power transmitter of claim 28, wherein the AC power has the first waveform or the second waveform different than the first waveform based on the state information of the wireless power receiver.

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