

(54) Title: INDUCTION HEATING COOKER POWER CONTROL CIRCUIT

(57) Abstract: The present invention relates to a power control circuit (1) suitable to be used in induction heating cookers, comprising an AC filter circuit (2) that filters the mains current; a bridge rectifier (3) that converts the alternative current received from the mains into direct current; a DC filter inductor (4) and a DC filter capacitor (5) that are disposed at the outlet of the bridge rectifier (3) on the DC line; an induction coil (6) that is energized for heating the vessel (16) placed onto the induction heating cooker; at least one resonant capacitor (7) that energizes the induction coil (6); at least one power switch (8), for example an IGBT (Insulated Gate Bipolar Transistor) that enables the resonant capacitor (7) to be charged/discharged and that provides the transmission of power from the induction coil (6) to the vessel (16); a drive voltage (9) that enables the power switch (8) to be driven with a drive voltage at the desired level; a collector node (10) whereon the resonant voltage is generated, and a microcontroller (11) that regulates the operation of the power switch (8) by means of the drive circuit (9), the power control circuit (1) determining whether or not the ferromagnetic characteristics of the vessel (16) placed on the induction coil (6) are suitable for induction heating.
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Description

INDUCTION HEATING COOKER POWER CONTROL CIRCUIT

[0001] The present invention relates to an induction heating cooker that detects the ferromagnetic properties of the vessel placed thereon.

[0002] The induction heating cooker functions according to the principle of heating a cast iron or steel ferromagnetic cooking vessel with the magnetic field generated by the induction coil. In order to drive the induction coils generating the magnetic field, a high-level electric current is passed through the power switch (such as IGBT (Insulated Gate Bipolar Transistor), diode, MOSFET, etc.) on the electronic circuit. In the state of the art, half bridge series resonant (HBSR) circuits formed by using two power switches and two resonant capacitors are used for driving a single induction coil.

[0003] In the market, vessels suitable to be used on the induction heating cookers have different characteristics depending on the alloy they comprise. In other words, the ferromagnetic characteristics of the vessels are different. While aluminum alloy pots have low inductance values, cast iron vessels have high inductance values. Therefore, it is important to know the ferromagnetic characteristics of a vessel placed onto the induction heating cooker. When a vessel that has a low ferromagnetic quality, meaning that has a low capacity of converting magnetic energy into thermal energy is placed onto the induction heating cooker, the vessel cannot be heated in accordance with the selected power setting, causing increase in power consumption and damaging the electronic circuit.

[0004] The European Patent No. EP2034801 relates to an induction heating appliance that enables the user to be informed of the cooking capabilities of cookware suitable for induction heating.

[0005] The European Patent No. EP2282606 relates to an induction heating appliance control method. By comparing the resonant voltage with a constant reference voltage predetermined by the control unit, the presence or absence of a vessel present on the induction coil, and the resistivity and the amplitude thereof is determined.

[0006] In the European Patent No. EP1 629698, an induction cooking system
comprising a power inverter, a microprocessor, a protection circuit and a pan detection circuit is disclosed.

[0007] The aim of the present invention is the realization of a power control circuit that detects the ferromagnetic characteristics of the vessel placed onto the induction coil.

[0008] The induction heating cooker power control circuit realized in order to attain the aim of the present invention, explicated in the first claim and the respective thereof, comprises a microcontroller that calculates the vessel resistance and inductance according to the power drawn from the mains and to the current passing through the induction coil while the induction coil is energized at any power setting selected via the user interface and that decides whether or not the vessel is present by checking if the vessel inductance is between the predetermined lower and upper limit values, and the microcontroller deciding if the ferromagnetic characteristics of the vessel are suitable for induction cooking in the case that the vessel is present.

[0009] The microcontroller decides that the ferromagnetic characteristics of the vessel is not suitable if the inductance of the vessel is below the lower limit value.

[0010] The microcontroller decides that the vessel is not present on the induction heating cooker if the vessel inductance is above the upper limit value.

[0011] By using the calculated vessel inductance, the microcontroller determines the resonant frequency that provides the maximum power to be transmitted to the vessel.

[0012] The power control circuit of the present invention furthermore comprises a mains current monitoring circuit, an input voltage monitoring circuit, a coil current monitoring circuit that monitors the current of the induction coil and a capacitance voltage monitoring circuit that together provide the data required for the microcontroller to calculate the said vessel inductance.

[0013] The induction heating cooker power control circuit of the present invention quickly and correctly detects if the vessel is present on the cooker when the induction coil is energized and if the vessel is present, detects if the ferromagnetic characteristics thereof are suitable. The power control circuit
determines the resonant frequency suitable for the vessel type, thus decreasing the power consumption and preventing the electronic circuit components from being damaged.

[0014] The induction heating cooker realized in order to attain the aim of the present invention is illustrated in the attached figure, where:

[0015] Figure 1 - is the schematic view of the induction heating cooker power control circuit

[0016] The elements illustrated in the figures are numbered as follows:

[0017] 1 - Power control circuit
[0018] 2 - AC filter circuit
[0019] 3 - Bridge rectifier
[0020] 4 - Filter inductor
[0021] 5- Filter capacitor
[0022] 6 - Induction coil
[0023] 7 - Resonant capacitor
[0024] 8 - Power switch
[0025] 9 - Drive circuit
[0026] 10 - Collector node
[0027] 11 - Microcontroller
[0028] 12 - Mains current monitoring circuit
[0029] 13 - Input voltage monitoring circuit
[0030] 14 - Coil current monitoring circuit
[0031] 15 - Capacitance voltage monitoring circuit
[0032] 16 - Vessel
[0033] R: Vessel resistance
[0034] L: Vessel inductance
[0035] L-lower: Vessel inductance lower limit value
[0036] L-upper: Vessel inductance upper limit value
[0037] AC: Mains current (alternative current) input

[0038] The power control circuit (1) (also referred to as the inverter circuit) that is suitable to be used in induction heating cookers and that provides the generation of magnetic energy for heating a vessel (16) placed onto the induction heating cooker surface, comprises an AC filter circuit (2) that
filters the mains current; a bridge rectifier (3) that converts the alternative current received from the mains into direct current; a DC filter inductor (4) and a DC filter capacitor (5) that are disposed at the outlet of the bridge rectifier (3) on the DC line; an induction coil (6) that is energized for heating the vessel (16) placed onto the induction heating cooker; at least one resonant capacitor (7) that energizes the induction coil (6); at least one power switch (8), for example an IGBT (Insulated Gate Bipolar Transistor) that enables the resonant capacitor (7) to be charged/discharged and that provides the transmission of power from the induction coil (6) to the vessel (16); a drive voltage (9) that enables the power switch (8) to be driven with a drive voltage at the desired level; a collector node (10) whereon the resonant voltage is generated, and a microcontroller (11) that regulates the operation of the power switch (8) by means of the drive circuit (9).

[0039] The induction heating cooker is operated by means of an on-off button (not shown in the figures) and first electronic components such as the microcontroller (11) and the user interface (not shown in the figures) are activated. Afterwards, in order to heat the vessel at the desired power setting, the heating setting is selected via the user interface and the induction coil (6) is energized by the power control circuit (1).

[0040] The power control circuit (1) of the present invention comprises the microcontroller (11) that calculates the vessel resistance (R) depending on the power drawn from the mains and on the current passing through the induction coil (6) and calculates the vessel inductance (L) depending on the vessel resistance (R) while the induction coil (6) is energized during the power transmission from the induction heating cooker to the vessel (16) at any power setting selected via the user interface and that decides that the ferromagnetic characteristics of the vessel (16) are suitable for induction cooking and that continues induction heating if the vessel inductance (L) is between the predetermined vessel inductance lower limit (L-lower) and upper limit (L-upper) prerecorded in its memory (L-lower< L < L-upper).

[0041] The microcontroller (11) decides that the ferromagnetic characteristics of
the vessel (16) are not suitable if the calculated vessel inductance (L) is below the vessel inductance lower limit (L-lower) and ends the heating process, enabling the user to be warned audibly and/or visually by means of the user interface.

[0042] The microcontroller (11) decides that the vessel (16) is not present on the induction heating cooker if the calculated vessel inductance (L) is above the vessel inductance upper limit (L-upper) and ends the heating process, enabling the user to be warned audibly and/or visually by means of the user interface.

[0043] Moreover, by using the calculated actual vessel inductance (L), the microcontroller (11) determines the resonant frequency, in other words the minimum operation frequency, that provides the maximum power to be transmitted to the vessel (16). When the user selects the highest power setting, for example selects "9" on the power setting knob marked from 1 to 9, the resonant frequency determined by the microcontroller (11) by using the vessel inductance (L) is applied. Different resonant frequencies are determined for vessels (16) with different magnetic properties placed on the induction heating cooker. Thus, the vessels (16) of different types are enabled to be heated in accordance with the vessel inductance (L), decreasing the energy consumption.

[0044] In an embodiment of the present invention, the power control circuit (1) comprises a mains current monitoring circuit (12) connected to the DC line and an input voltage monitoring circuit (13) connected to the outlet of the bridge rectifier (3) that together provide the calculation of the power drawn from the mains in order to determine the vessel resistance (R).

[0045] The microcontroller (11) calculates the power drawn from the mains by calculating and using the root means square of the current values drawn from the mains according to the data received from the mains current monitoring circuit (12) and the root mean square of the input voltage values according to the data received from the input voltage monitoring circuit (13).

[0046] In this embodiment, the power control circuit (1) furthermore comprises a coil current monitoring circuit (14) that provides the calculation of the
vessel resistance (R) by the microcontroller (11), that is connected to the induction coil (6) and that monitors the current passing through the induction coil (6).

[0047] The microcontroller (11) calculates the maximum current value passing through the induction coil (6) according to the data received from the coil current monitoring circuit (14) and also calculates the vessel resistance (R) by using the ratio of the power drawn from the mains to the said maximum current value.

[0048] In another embodiment of the present invention, the power control circuit (1) comprises a capacitance voltage monitoring circuit (15) that provides the calculation of the vessel inductance (L) by the microcontroller (11) and that is connected to the collector node (10).

[0049] The microcontroller (11) determines the maximum capacitance voltage according to the data received from the capacitance voltage monitoring circuit (15) and calculates the vessel inductance (L) by using the previously calculated vessel resistance (R).

[0050] In another embodiment of the present invention, the power control circuit (1) is a half bridge series resonant (HBSR) circuit comprising a pair of resonant capacitors (7) and a pair of power switches (8).

[0051] In another embodiment of the present invention, the power control circuit (1) is a single switch quasi resonant (SSQR) circuit comprising a single resonant capacitor (7) and a single power switch (8). In some embodiments, it is known as single-ended inverter circuit.

[0052] In the induction heating cooker power control circuit (1) of the present invention, the microcontroller (11) decides whether or not the ferromagnetic characteristics of the vessel (16) are suitable by calculating the vessel inductance (L) when the induction coil (6) is energized. If the vessel inductance (L) is between the predetermined lower and upper limit values (L-lower and L-upper), the heating process is continued, providing an efficient transmission of power in accordance with the characteristics of the vessel (16). If the vessel (16) is not suitable, the energy transmission is terminated, thus preventing the electronic circuit components from being damaged with high current.
Claims

1. A power control circuit (1) suitable to be used in induction heating cookers, comprising an AC filter circuit (2) that filters the mains current; a bridge rectifier (3) that converts the alternative current received from the mains into direct current; a DC filter inductor (4) and a DC filter capacitor (5) that are disposed at the outlet of the bridge rectifier (3) on the DC line; an induction coil (6) that is energized for heating the vessel (16) placed onto the induction heating cooker; at least one resonant capacitor (7) that energizes the induction coil (6); at least one power switch (8) that enables the resonant capacitor (7) to be charged/discharged and that provides the transmission of power from the induction coil (6) to the vessel (16); a drive circuit (9) that enables the power switch (8) to be driven with a drive voltage at the desired level; a collector node (10) whereon the resonant voltage is generated, and a microcontroller (11) that regulates the operation of the power switch (8) by means of the drive circuit (9), characterized by the microcontroller (11) that calculates the vessel resistance (R) depending on the power drawn from the mains and on the current passing through the induction coil (6) and calculates the vessel inductance (L) depending on the vessel resistance (R) while the induction coil (6) is energized at any power setting selected via the user interface and that decides that the ferromagnetic characteristics of the vessel (16) are suitable for induction cooking and that continues induction heating if the vessel inductance (L) is between the predetermined vessel inductance lower limit (L-lower) and upper limit (L-upper) prerecorded in its memory.

2. A power control circuit (1) as in Claim 1, characterized by the microcontroller (11) that decides that the ferromagnetic characteristics of the vessel (16) are not suitable if the vessel inductance (L) is below the lower limit (L-lower) and ends the heating process, enabling the user to be warned audibly and/or visually by means of the user interface.

3. A power control circuit (1) as in Claim 1, characterized by the microcontroller (11) that decides that the vessel (16) is not present on the induction heating cooker if the vessel inductance (L) is above the upper limit (L-upper) and ends the heating process, enabling the user to be warned audibly and/or visually by means of the user interface.
4. A power control circuit (1) as in any one of the Claims 1 to 3, characterized by the microcontroller (11) that determines the resonant frequency providing the maximum power to be transmitted to the vessel (16) by using the calculated vessel inductance (L).

5. A power control circuit (1) as in Claim 1, characterized by a mains current monitoring circuit (12) connected to the DC line and an input voltage monitoring circuit (13) connected to the outlet of the bridge rectifier (3) that together provide the calculation of the power drawn from the mains in order to determine the vessel resistance (R).

6. A power control circuit (1) as in Claim 5, characterized by the microcontroller (11) that calculates the power drawn from the mains by calculating and using the root mean square of the current values drawn from the mains according to the data received from the mains current monitoring circuit (12) and the root mean square of the input voltage values according to the data received from the input voltage monitoring circuit (13).

7. A power control circuit (1) as in Claim 1, characterized by a coil current monitoring circuit (14) that provides the calculation of the vessel resistance (R) by the microcontroller (11), that is connected to the induction coil (6) and that monitors the current of the induction coil (6).

8. A power control circuit (1) as in Claim 7, characterized by the microcontroller (11) that calculates the maximum current value passing through the induction coil (6) according to the data received from the coil current monitoring circuit (14) and also calculates the vessel resistance (R) by using the ratio of the power drawn from the mains to the said maximum current value.

9. A power control circuit (1) as in Claim 1, characterized by a capacitance voltage monitoring circuit (15) that provides the calculation of the vessel inductance (L) by the microcontroller (11) and that is connected to the collector node (10).

10. A power control circuit (1) as in Claim 9, characterized by the microcontroller (11) that determines the maximum capacitance voltage value according to the data received from the capacitance voltage monitoring circuit (15) and calculates the vessel inductance (L) by using the vessel resistance (R).

11. A power control circuit (1) as in Claim 1, characterized by being a half bridge
series resonant circuit comprising a pair of resonant capacitors (7) and a pair of power switches (8).

12. A power control circuit (1) as in Claim 1, characterized by being a single switch quasi resonant circuit comprising a single resonant capacitor (7) and a single power switch (8).

13. An induction heating cooker, characterized by a power control circuit (1) as in Claim 1.
**INTERNATIONAL SEARCH REPORT**

**A. CLASSIFICATION OF SUBJECT MATTER**

**INV.** H05B6/06

**ADD.**

According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)

H05B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

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[X] Further documents are listed in the continuation of Box C.  
[ ] See patent family annex.

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Authorized officer: Garcia, Jesus
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