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(54) INDUCTION HOB AND METHOD FOR OPERATING AN INDUCTION HOB

INDUKTIONSKOCHFELD UND VERFAHREN ZUR BEDIENUNG EINES INDUKTIONSKOCHFELDS

PLAQUE DE CUISSON À INDUCTION ET PROCÉDÉ DE FONCTIONNEMENT D'UNE TELLE PLAQUE

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Description

[0001] The present invention relates generally to the field of induction hobs. More specifically, the present invention is related to an induction hob comprising a power circuit in which the functionality of a current transducer is replaced by arithmetic functionality provided by a control entity.

BACKGROUND OF THE INVENTION

[0002] Induction hobs for preparing food are well known in prior art. Induction hobs typically comprise at least one induction coil placed below a hob plate in order to heat a piece of cookware.

[0003] For controlling the induction hob, values regarding the peak current flowing through the induction coil and power factor indicating the load of the induction coil (dependent of the position of the piece of cookware, the material of the piece of cookware etc.) are required.

[0004] Common induction hobs comprise a current transducer based on which peak current flowing through the induction coil and a power factor can be determined. However, the usage of a current transducer is disadvantageous because the total costs and footprint of the power circuit board is increased.

[0005] Document US 2014/197160 A1 discloses systems and methods for protecting switching elements in an induction heating system.

[0006] Document US 2009/057299 A1 discloses an induction cooking appliance and a method for checking the cooking capabilities of a piece of cookware.

[0007] Document GB 2 524 102 A discloses a switched mode AC-DC converter.

SUMMARY OF THE INVENTION

[0008] It is an objective of the embodiments of the invention to provide an induction hob, which is improved with respect to the costs and footprint of the power circuit board. The objective is solved by the features of the independent claims. Preferred embodiments are given in the dependent claims. If not explicitly indicated otherwise, embodiments of the invention can be freely combined with each other.

[0009] According to an aspect, the invention relates to an induction hob comprising a circuitry for powering at least one induction coil. The circuitry comprises a power circuit portion with at least one switching element adapted to provide pulsed electric power to said induction coil and an oscillating circuit portion. Said induction coil is electrically coupled with said power circuit portion and said oscillating circuit portion. The induction hob further comprises a control entity being configured to receive first information correlated with a first voltage provided at said power circuit portion and second information correlated with a second voltage correlated with said oscillating circuit portion. Said control entity is further configured to calculate information regarding a peak value and a power factor of the electric current provided through said induction coil based on said received first and second information.

[0010] Said induction hob is advantageous because the functionality of the current transducer can be replaced by a mathematical approach, said mathematical approach taking available information of the power circuit of the induction hob. Said control entity is configured to calculate peak current value and power factor value based on said available information. Thereby, the total costs and footprint of the power circuit can be reduced, specifically when using existing resources (e.g. microprocessor etc.) for calculating said values.

[0011] According to embodiments, the said first information is indicative for a voltage provided at a circuit node located between a pair of switching elements. Preferably, said switching elements may be arranged according to a half-bridge converter and said circuit node is located between the switching elements of the half-bridge converter. For example, the switching elements may be IGBTs (IGBT: insulated-gate bipolar transistor). Said induction coil may be at least indirectly, preferably directly electrically coupled with said circuit node.

[0012] According to embodiments, said first information is calculated by considering information regarding rectified mains voltage and duty cycle information.

[0013] According to embodiments, said first information is calculated based on the following formula:

$$V_m = \frac{2 \cdot V_{MAIN\_S}}{\pi} \cdot \sin(\pi \cdot duty);$$

wherein

V_{MAIN_S} is the peak value of rectified mains voltage; and
duty is duty cycle information.

[0014] According to embodiments, said second information is indicative for a voltage provided at a circuit node located between a pair of capacitors included in said oscillating circuit. Said circuit node may be used for electrically coupling the induction coil with the oscillating circuit. One capacitor of said pair of capacitors extends between said circuit node and supply voltage wherein the other capacitor of said pair of capacitors extends between said circuit node and ground.

[0015] According to embodiments, said second information is obtained using sensing circuit portion comprising a voltage divider. Said voltage divider may be formed by two or more resistors which allow the measurement of second information.

[0016] According to embodiments, said second information is obtained by sampling the voltage at a circuit node of said oscillating circuit, specifically by sampling the voltage at a circuit node located between a pair of capacitors included in said oscillating circuit. Said sampling may be performed continuously or intermittent (discontinuously). Thereby, system resources can be saved.

[0017] According to embodiments, said second information comprises information regarding the maximum and minimum values of the voltage at a circuit node located between a pair of capacitors included in said oscillating circuit. For determining the peak value of the coil current, only maximum and minimum peak values of the circuit node of the oscillating circuit are required. Said maximum and minimum values may be averaged values e.g. averaged over the half of the mains voltage period.

[0018] According to embodiments, the control entity is configured to calculate the peak value of the electric current provided through said induction coil based on the following formula:

$$I_C = 2\pi f (V_{C,max} - V_{C,min}) C_{res,2}$$

wherein

- f is the frequency of the AC-current provided to the induction coil;
- $V_{C,max}$ is the maximum value of the voltage provided at a node between a pair of capacitors included in said oscillating circuit;
- $V_{C,min}$ is the minimum value of the voltage provided at a node between a pair of capacitors included in said oscillating circuit; and
- $C_{res,2}$ is the capacitor value of a resonance capacitor included in said oscillating circuit.

[0019] According to embodiments, the control entity is configured to calculate the power factor based on two or more values of first information and two or more values of second information, wherein the two or more values of first and second information are obtained by driving the induction coil at different frequencies.

[0020] According to embodiments, the control entity is configured to calculate the power factor based on an averaged frequency value, said averaged frequency value being obtained by calculating the arithmetic mean of two or more frequency values.

[0021] According to embodiments, the control entity is configured to calculate the power factor based on information regarding a load resistance value and a load inductance value, said load resistance value forming the real part and said load inductance value forming the complex part of complex load impedance. Based on said electrical model of the electric load provided by the induction coil (which is loaded by means of the piece of cookware placed above the induction coil) a calculation of the power factor with limited mathematical effort is possible.

[0022] According to embodiments, the control entity is configured to calculate the power factor based on the following formula:

$$cos\varphi = \frac{R_s}{\sqrt{{R_s}^2 + (\omega_{av} L_S - \frac{1}{\omega_{av}^2 {C_{res}}^2})^2}}$$

wherein

- R_s is the load resistance value;
- L_S is the load inductance value;
- ω_{av} is an averaged frequency value; and

C_{res} is the capacitor value of the capacitor included in said oscillating circuit.

[0023] According to embodiments, the induction hob comprises no current transducer electrically coupled with the induction coil, wherein information regarding a peak value and a power factor of the electric current provided through said induction coil are provided by an algorithm considering said first and second information. Thereby, the complexity of the power circuit is significantly reduced.

[0024] According to a further aspect, the invention relates to a method for operating an induction hob. The induction hob comprises a circuitry for powering at least one induction coil. The circuitry comprises a power circuit portion with at least one switching element adapted to provide pulsed electric power to said induction coil and an oscillating circuit portion, said induction coil being electrically coupled with said power circuit portion and said oscillating circuit. The induction hob comprises a control entity performing the steps of:

- receiving first information correlated with a first voltage provided at said power circuit portion;
- receiving second information correlated with a second voltage correlated with said oscillating circuit portion;
- calculating information regarding a peak value and a power factor of the electric current provided through said induction coil based on said received first and second information.

[0025] "Power factor" according to the present invention refers to a value reflecting the ratio of a real part of a complex impedance and the complex impedance. Based on said power factor, the coupling between the piece of cookware and the induction coil can be assessed.

[0026] "Duty cycle" according to the present invention refers to the fraction of one signal period in which a signal is active/high. Specifically, "Duty cycle" according to the present invention refers to the fraction at which the switching element is switched on (high) compared to the whole switching period.

[0027] The term "essentially" or "approximately" as used in the invention means deviations from the exact value by +/- 10%, preferably by +/- 5% and/or deviations in the form of changes that are insignificant for the function.

BRIEF DESCRIPTION OF THE DRAWINGS

[0028] The various aspects of the invention, including its particular features and advantages, will be readily understood from the following detailed description and the accompanying drawings, in which:

Fig. 1 shows an example embodiment of a schematic power circuit of a state-of-the-art induction hob;

Fig. 2 shows an example embodiment of a schematic power circuit of an induction hob according to the present invention; and

Fig. 3 shows an equivalent circuit of a power circuit according to the present invention.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

[0029] The present invention will now be described more fully with reference to the accompanying drawings, in which example embodiments are shown. However, this invention should not be construed as limited to the embodiments set forth herein. Throughout the following description similar reference numerals have been used to denote similar elements, parts, items or features, when applicable.

[0030] Fig. 1 shows a schematic diagram of a power circuit 1 of a state-of-the-art induction hob. The power circuit 1 comprises an input stage 2. Said input stage 2 may be coupled with AC mains, e.g. 230V AC mains. Said input stage 2 may be adapted to rectify and/or filter the AC mains voltage. Specifically, the input stage 2 may comprise a rectification bridge. In addition, the power circuit 1 may comprise a coil driver entity 3. The coil driver entity 3 may be adapted to control one or more switching elements 4, 5. Said switching elements 4, 5 may be electrically coupled with said input stage 2 in order to receive rectified AC voltage. In addition, said coil driver entity 3 may be electrically coupled with control inputs of said switching elements 4, 5 in order to be able to provide pulsed electrical power to an induction coil 6. Said switching elements 4, 5 may be, for example, IGBTs. The IGBTs may be integrated in a power circuit portion 7, said power circuit portion 7 being configured as a half-bridge converter.

[0031] Between said power circuit portion 7 and said induction coil 6, a current transducer 8 is provided. Said current transducer 8 may be adapted to provide information regarding the peak value of the electric current provided through the induction coil 6 (in the following referred to as coil current) and the power factor. More in detail, the coil current may flow through the current transducer 8. Thereby, the current transducer 8 is able to measure/determine the peak value of the coil current and the power factor. The current transducer 8 may be electrically coupled with a circuit node 7a of the power circuit portion 7 which is arranged between the pair of switching elements 4, 5.

[0032] At the opposite side of the current transducer 8, the induction coil 6 is coupled with an oscillating circuit portion. Said oscillating circuit portion 9 may comprise a pair of capacitors 9.1, 9.2, said capacitors 9.1, 9.2 forming together with the inductivity of the induction coil 6 an electrical resonant or quasi-resonant circuit which enables an oscillating excitation of the induction coil 6. The induction coil 6 may be coupled with a circuit node 9a being arranged between said pair of capacitors 9.1, 9.2.

[0033] Said transducer 8 may be electrically coupled with a control entity 10 for providing information regarding the peak value of the coil current and the power factor to said control entity 10. Based on said information, the control entity 10 controls the switching elements 4, 5 of the power circuit portion 7.

[0034] Fig. 2 shows a schematic diagram of a power circuit 1a of an induction hob according to the present invention. The basic structure of the power circuit 1a is similar to the structure of the power circuit 1. Therefore, in the following only differences of the power circuit 1a with respect to power circuit 1 are explained. Apart from that, the features described before do also apply to the embodiment of Fig. 2.

[0035] The first main difference to the power circuit 1 is that the power circuit 1a does not comprise a current transducer 8. More in detail, the induction coil 6 is directly coupled with the circuit node 7.1 provided between the pair of switching elements 4, 5. A further difference is the voltage divider 11 which is electrically coupled with the circuit node 9a of the oscillating circuit portion 9. In order to be able to replace the functionality of the current transducer 8, the control entity 10 is configured to gather information regarding the peak value of the coil current and the power factor based on a mathematical algorithm. More in detail, the control entity 10 may receive certain information available at the power circuit 1a, e.g. information correlated with the voltage of the circuit node 7a and a voltage of the circuit node 9a. The wording "information correlated with a voltage" may refer to the case that a voltage is tapped at a certain node (e.g. node 7a or 9a) thereby said information being the voltage value at said node. However, the wording "information correlated with a voltage" may alternatively be indicative for said voltage at said node, but may be derived by an arithmetic operation based on other parameters.

[0036] In the following, the implementation of calculating information regarding the peak value of the coil current and the power factor is described in detail.

[0037] The algorithmic implementation (and not based on a current transducer) of providing information regarding the peak value of the coil current and the power factor can be obtained based on several information available at the power circuit 1a or derivable from information available at the power circuit 1a.

[0038] In the arithmetic implementation, the voltage V_m (middle point voltage) at circuit node 7a (middle point of the half bridge converter) is determined. Voltage V_m is typically a rectangular, pulse-width-modulated wave. Its amplitude can be computed considering the voltage $V_{\_Main\_S}$ provided to the power circuit portion 7 and the related duty cycle. Preferably, $V_{\_Main\_S}$ is the rectified sinusoidal wave or a DC-voltage.

[0039] Specifically, the following equation can be used for calculating the voltage V_m:

$$V_m = \frac{2 \cdot V_{MAIN\_S}}{\pi} \cdot \sin(\pi \cdot duty); \quad \text{(equ.1)}$$

wherein

V_{MAIN_S} is the peak value of rectified mains voltage; and
duty is duty cycle information.

[0040] Furthermore, a voltage V_c at a circuit node 9a (node included in the oscillating circuit portion 9) is determined. Said voltage V_c may be a voltage which drops at a resonance capacitor $C_{res,\,2}$ 9.2 of the oscillating circuit portion 9.

[0041] For determining voltage V_c, the power circuit comprises a sensing circuit portion. Said sensing circuit portion may comprise a voltage divider 11. Voltage V_c may be a sinusoidal or essentially sinusoidal AC voltage. For determining peak current I_c flowing through the induction coil 6, information regarding the maximum and minimum value of voltage V_c are required. Said maximum and minimum values of voltage V_c may be obtained by sampling the voltage V_c occurring at the sensing circuit portion. The sampling frequency may be, for example, 1MHz or higher in order to obtain a high resolution of the sampled voltage. Said sampling may be obtained continuously or intermittent. For example, one or more periods of voltage V_c may be sampled every lOOps (corresponding to a repetition frequency of 10KHz).

[0042] Fig. 3 shows an equivalent circuit covering the power circuit portion 7, the induction coil 6 and the oscillating circuit 9 of the power circuit 1a according to Fig. 2. The induction coil 6 is replaced by a load representation modelled by R_s and L_s. The values of R_s and L_s depend on the applied frequency, the temperature, the material of the piece of cookware placed on the induction coil and the position of the piece of cookware with respect to the induction coil 6. Based on said equivalent circuit, the coil current I_c can be reconstructed using the following model equations:

$$V_m = V_1 + V_c;$$

$$I_1 = I_{cL} + I_{cH};$$

$$\frac{dV_c}{dt} = \frac{I_1}{2C_{res,2}};$$

$$I_C = I_1 = 2C_{res,2} \cdot \frac{dV_c}{dt};$$

[0043] Based on the last formula, coil current I_c can be reconstructed as follows:

$$I_C = 2\pi f(V_{C,max} - V_{C,min})C_{res,2}; \quad \text{(equ.2)}$$

wherein

f is the frequency of the AC-current provided to the induction coil 6;
$V_{C,max}$ is the maximum value of the voltage provided at circuit node 9a;
$V_{C,min}$ is the minimum value of the voltage provided at circuit node 9a; and
$C_{res,2}$ is the capacitor value of a resonance capacitor included in said oscillating circuit.

[0044] In the following, an example embodiment of determining power factor is provided. For reconstructing the power factor, the load can be modelled based on an equivalent R-L-model. The mathematical formulation starts considering a representation in the Laplace-domain:

$$F(s) = \int_0^\infty f(t)e^{-st}dt;$$

wherein s is a complex frequency parameter $s = \sigma + j\omega$.

[0045] Considering a matrix representation of s:

$$s = \begin{bmatrix} 0 & -1 \\ 1 & 0 \end{bmatrix}.$$

[0046] The voltage V_m at circuit node 7a and V_c at circuit node 9a can be represented by its real (r) and imaginary (i) components:

$$V_m = \begin{bmatrix} V_{m,r} \\ V_{m,i} \end{bmatrix};$$

$$V_c = \begin{bmatrix} V_{c,r} \\ V_{c,i} \end{bmatrix};$$

[0047] Considering the relationships

$$V_{R_S} = R_S \cdot I_{R_S};$$

$$V_{L_s} = s \cdot L_S \cdot I_{L_s};$$

$$I_{C_s} = s \cdot C_{res,2} \cdot V_{C_{res,2}};$$

the main equation for the equivalent circuit is:

$$0 = V_m - V_c - \left(\begin{bmatrix} 0 & -1 \\ 1 & 0 \end{bmatrix} \cdot R_S + s \cdot L_S\right) \cdot 2sC_{res,2}V_c;$$

[0048] For calculating the power factor, multiple values at different frequencies have to be gathered. More in detail, values at a first frequency f1 and a second frequency f2 are gathered wherein f1 < f2.

[0049] Considering the voltages:

$$V_{m.1} = \frac{2 \cdot V_{MAINS,1}}{\pi} \cdot \sin(\pi \cdot duty_1);$$

$$V_{m.2} = \frac{2 \cdot V_{MAINS,2}}{\pi} \cdot \sin(\pi \cdot duty_2);$$

$$V_{c.1} = \frac{V_{cMax,1} - V_{cMin,1}}{2};$$

$$V_{c.2} = \frac{V_{cMax,2} - V_{cMin,2}}{2};$$

substituting the previous real/imaginary notation considering $V_{m,r} = \sqrt{V_m^2}$ and $V_{m,i}$=0 can be obtained:

$$R_{S1} = R_S(f1) = \frac{-V_{c1,i} \cdot V_{m.1}}{2C_{res}(V_{c.1.i}^2 + V_{c.1.r}^2)};$$

$$R_{S2} = R_S(f2) = \frac{-V_{c2,i} \cdot V_{m.2}}{2C_{res.2}(V_{c.2.i}^2 + V_{c.2.r}^2)}$$

$$L_{S1} = L_S(f1) = \frac{{V_{c1,i}}^2 - V_{c1,r}V_{m.1} + {V_{c1,r}}^2}{2C_{res.2}({V_{c1,i}}^2 + {V_{c1,r}}^2)\omega_1^2} \; with \; \omega_1 = 2\pi f1$$

$$L_{S2} = L_S(f2) = \frac{{V_{c2,i}}^2 - V_{c2,r}V_{m.2} + {V_{c2,r}}^2}{2C_{res.2}({V_{c2,i}}^2 + {V_{c2,r}}^2)\omega_2^2} \; with \; \omega_2 = 2\pi f2$$

[0050] Solving the defined system:

$$\begin{cases} R_{S1} - Rs \\ R_{S2} - Rs \\ L_{S1} - Ls \\ L_{S2} - Ls \\ {V_{c1,i}}^2 + {V_{c1,r}}^2 - {V_{c1}}^2 \\ {V_{c2,i}}^2 + {V_{c2,r}}^2 - {V_{c2}}^2 \end{cases} \quad in\ R_s, L_S, V_{c1,i}, V_{c1,r}, V_{c2,i}, V_{c2,r}$$

a formulation for the power factor can be obtained. The power factor represents the ratio between the real part of the load impedanz in relation to the complex load impedance (i.e. $\cos\varphi = \frac{R_S}{Z_S}$).

$$cos\varphi = \frac{Rs}{\sqrt{Rs^2 + \left(\omega_{av} L_S - \frac{1}{\omega_{av} 2 C_{res}}\right)^2}}$$

wherein:

$$\omega_{av} = \frac{(\omega_1 + \omega_2)}{2}.$$

[0051] It should be noted that the description and drawings merely illustrate the principles of the proposed induction hob. Those skilled in the art will be able to implement various arrangements that, although not explicitly described or shown herein, embody the principles of the invention.

List of reference numerals

[0052]

1, 1a	power circuit
2	input stage
3	coil driver entity
4	switching element
5	switching element
6	induction coil
7	power circuit portion
7a	circuit node
8	current transducer
9	oscillating circuit portion
9a	circuit node
9.1	capacitor
9.2	capacitor
10	control entity
11	voltage divider

Claims

1. Induction hob comprising a circuitry (1a) for powering at least one induction coil (6), the circuitry (1a) comprising a power circuit portion (7) with at least one switching element (4, 5) adapted to provide pulsed electric power to said induction coil (6) and an oscillating circuit portion (9), said induction coil (6) being electrically coupled with said power circuit portion (7) and said oscillating circuit portion (9), wherein said induction hob comprises a control entity (10),

the induction hob being **characterized in that** said control entity (10) is configured to receive first information correlated with a first voltage provided at said power circuit portion (7) and second information correlated with a second voltage correlated with said oscillating circuit portion (9), said control entity (10) being further configured to calculate information regarding a peak value and a power factor of the electric current provided through said induction coil (6) based on said received first and second information.

2. Induction hob according to claim 1, wherein said first information is indicative for a voltage (V_m) provided at a circuit node (7a) located between a pair of switching elements (4, 5) .

3. Induction hob according to claim 1 or 2, wherein said first information is calculated by considering information regarding rectified mains voltage (V_{main_s}) and duty cycle information (duty).

4. Induction hob according to anyone of the preceding claims, wherein said first information is calculated based on the following formula:

$$V_m = \frac{2 \cdot V_{MAIN\_S}}{\pi} \cdot \sin(\pi \cdot duty);$$

wherein

V_{MAIN_S} is the peak value of rectified mains voltage; and
duty is duty cycle information.

5. Induction hob according to anyone of the preceding claims, wherein said second information is indicative for a voltage (V_c) provided at a circuit node (9a) located between a pair of capacitors ($C_{res,1}$, $C_{res,2}$) included in said oscillating circuit portion (9).

6. Induction hob according to anyone of the preceding claims, wherein said second information is obtained using sensing circuit portion comprising a voltage divider (11).

7. Induction hob according to claim 5 or 6, wherein said second information is obtained by sampling the voltage (V_c) at a circuit node (9a) of said oscillating circuit portion (9), specifically by sampling the voltage (V_c) at a circuit node (9a) located between a pair of capacitors ($C_{res,1}$, $C_{res,2}$) included in said oscillating circuit portion (9).

8. Induction hob according to anyone of the preceding claims, wherein said second information comprises information regarding the maximum and minimum values of the voltage (V_c) at a circuit node (9a) located between a pair of capacitors ($C_{res,1}$, $C_{res,2}$) included in said oscillating circuit portion (9) .

9. Induction hob according to anyone of the preceding claims, wherein the control entity (11) is configured to calculate the peak value of the electric current provided through said induction coil (6) based on the following formula:

$$I_C = 2\pi f(V_{C,max} - V_{C,min})C_{res,2}$$

wherein

f is the frequency of the AC-current provided to the induction coil;
$V_{C,max}$ is the maximum value of the voltage provided at a node between a pair of capacitors included in said oscillating circuit;
$V_{C,min}$ is the minimum value of the voltage provided at a node between a pair of capacitors included in said oscillating circuit; and
$C_{res,2}$ is the capacitor value of a resonance capacitor included in said oscillating circuit.

10. Induction hob according to anyone of the preceding claims, wherein the control entity (11) is configured to calculate the power factor based on two or more values of first information and two or more values of second information, wherein the two or more values of first and second information are obtained by driving the induction coil (6) at different frequencies.

11. Induction hob according to anyone of the preceding claims, wherein the control entity (11) is configured to calculate the power factor based on an averaged frequency value, said averaged frequency value being obtained by calculating the arithmetic mean of two or more frequency values.

12. Induction hob according to anyone of the preceding claims, wherein the control entity (11) is configured to calculate the power factor based on information regarding a load resistance value (R_s) and a load inductance value (L_s) said load resistance value (R_s) forming the real part and said load inductance value (L_s) forming the complex part of a complex load impedance.

13. Induction hob according to anyone of the preceding claims, wherein the control entity (11) is configured to calculate the power factor based on the following formula:

$$cos\varphi = \frac{R_s}{\sqrt{{R_s}^2 + (\omega_{av} L_S - \frac{1}{\omega_{av}^2 {C_{res}}^2})^2}}$$

wherein

R_s is the load resistance value;
L_S is the load inductance value;
ω_{av} is an averaged frequency value; and
C_{res} is the capacitor value of the capacitor included in said oscillating circuit.

14. Induction hob according to anyone of the preceding claims, comprising no current transducer electrically coupled with the induction coil (6), wherein information regarding a peak value and a power factor of the electric current provided through said induction coil are provided by an algorithm considering said first and second information.

15. Method for operating an induction hob, the induction hob comprising a circuitry (1a) for powering at least one induction coil (6), the circuitry (1a) comprising a power circuit portion (7) with at least one switching element (4, 5) adapted to provide pulsed electric power to said induction coil (6) and an oscillating circuit portion (9), said induction coil being electrically coupled with said power circuit portion (7) and said oscillating circuit portion (9), wherein said induction hob comprises a control entity (11) performing the steps of:

- receiving first information correlated with a first voltage (V_m) provided at said power circuit portion (7);
- receiving second information correlated with a second voltage (V_c) correlated with said oscillating circuit portion (9);
- calculating information regarding a peak value and a power factor of the electric current provided through said induction coil based on said received first and second information.

Patentansprüche

1. Induktionsherd, der eine Schaltungsanordnung (1a) umfasst, um wenigstens eine Induktionsspule (6) mit Leistung zu versorgen, wobei die Schaltungsanordnung (1a) einen Leistungsschaltungsabschnitt (7) mit wenigstens einem Schaltelement (4, 5), der ausgelegt ist, gepulste elektrische Leistung für die Induktionsspule (6) bereitzustellen, und einen Schwingkreisabschnitt (9) umfasst, wobei die Induktionsspule (6) mit dem Leistungsschaltungsabschnitt (7) und dem Schwingkreisabschnitt (9) elektrisch gekoppelt ist, wobei
der Induktionsherd eine Steuereinheit (10) umfasst, wobei der Induktionsherd **dadurch gekennzeichnet ist, dass** die Steuereinheit (10) so konfiguriert ist, dass sie erste Informationen, die sich auf eine erste Spannung beziehen, die bei dem Leistungsschaltungsabschnitt (7) bereitgestellt wird, und zweite Informationen, die sich auf eine zweite Spannung beziehen, die sich auf den Schwingkreisabschnitt (9) bezieht, erhält, wobei die Steuereinheit (10) ferner so konfiguriert ist, dass sie Informationen bezüglich eines Spitzenwerts und eines Leistungsfaktors des elektrischen Stroms, der durch die Induktionsspule (6) bereitgestellt wird, auf der Basis der erhaltenen ersten und zweiten

Informationen berechnet.

2. Induktionsherd nach Anspruch 1, wobei die ersten Informationen eine Spannung (V_m) anzeigen, die bei einem Schaltungsknoten (7a) vorliegt, der sich zwischen einem Paar Schaltelemente (4, 5) befindet.

3. Induktionsherd nach Anspruch 1 oder 2, wobei die ersten Informationen durch Berücksichtigen von Informationen bezüglich einer gleichgerichteten Netzspannung (V_{main_s}) und Tastgradinformationen (duty) berechnet werden.

4. Induktionsherd nach einem der vorhergehenden Ansprüche, wobei die ersten Informationen auf der Basis der folgenden Formel berechnet werden:

$$V_m = \frac{2 \cdot V_{MAIN\_S}}{\pi} \cdot \sin(\pi \cdot duty);$$

wobei

V_{MAIN_S} der Spitzenwert der gleichgerichteten Netzspannung ist; und
duty die Tastgradinformationen sind.

5. Induktionsherd nach einem der vorhergehenden Ansprüche, wobei die zweiten Informationen eine Spannung (V_c) anzeigen, die bei einem Schaltungsknoten (9a) vorliegt, der sich zwischen einem Paar Kondensatoren ($C_{res,1}$, $C_{res,2}$), die in dem Schwingkreisabschnitt (9) enthalten sind, befindet.

6. Induktionsherd nach einem der vorhergehenden Ansprüche, wobei die zweiten Informationen erhalten werden, indem ein Messkreisabschnitt verwendet wird, der einen Spannungsteiler (11) umfasst.

7. Induktionsherd nach Anspruch 5 oder 6, wobei die zweiten Informationen erhalten werden, indem die Spannung (V_c) bei einem Schaltungsknoten (9a) des Schwingkreisabschnitts (9) abgetastet wird, insbesondere durch Abtasten der Spannung (V_c) bei einem Schaltungsknoten (9a), der sich zwischen einem Paar Kondensatoren ($C_{res,1}$, $C_{res,2}$), das in dem Schwingkreisabschnitt (9) enthalten ist, befindet.

8. Induktionsherd nach einem der vorhergehenden Ansprüche, wobei die zweiten Informationen Informationen bezüglich der Maximal- und Minimalwerte der Spannung (V_c) an einem Schaltungsknoten (9a) umfassen, der sich zwischen einem Paar Kondensatoren ($C_{res,1}$, $C_{res,2}$), die in dem Schwingkreisabschnitt (9) enthalten sind, befindet.

9. Induktionsherd nach einem der vorhergehenden Ansprüche, wobei die Steuereinheit (11) so konfiguriert ist, dass sie den Spitzenwert des elektrischen Stroms, der durch die Induktionsspule (6) bereitgestellt wird, auf der Basis der folgenden Formel berechnet:

$$I_C = 2\,\pi\,f\left(V_{C,max} - V_{C,min}\right)C_{res,2},$$

wobei:

f die Frequenz des Wechselstroms ist, der für die Induktionsspule bereitgestellt wird;
$V_{c,max}$ der Maximalwert der Spannung ist, die an einem Knoten zwischen einem Paar Kondensatoren, das in dem Schwingkreis enthalten ist, bereitgestellt wird;
$V_{c,min}$ der Minimalwert der Spannung ist, die an einem Knoten zwischen einem Paar Kondensatoren, das in dem Schwingkreis enthalten ist, bereitgestellt wird; und
$C_{res,2}$ der Kapazitätswert eines Resonanzkondensators ist, der in dem Schwingkreis enthalten ist.

10. Induktionsherd nach einem der vorhergehenden Ansprüche, wobei die Steuereinheit (11) so konfiguriert ist, dass sie den Leistungsfaktor auf der Basis von zwei oder mehreren Werten der ersten Informationen und zwei oder mehreren Werten der zweiten Informationen berechnet, wobei die zwei oder mehreren Werte der ersten und der zweiten Informationen durch Ansteuern der Induktionsspule (6) bei verschiedenen Frequenzen erhalten werden.

11. Induktionsherd nach einem der vorhergehenden Ansprüche, wobei die Steuereinheit (11) so konfiguriert ist, dass

sie den Leistungsfaktor auf der Basis eines gemittelten Frequenzwerts berechnet, wobei der gemittelte Frequenzwert erhalten wird, indem das arithmetische Mittel von zwei oder mehreren Frequenzwerten berechnet wird.

12. Induktionsherd nach einem der vorhergehenden Ansprüche, wobei die Steuereinheit (11) so konfiguriert ist, dass sie den Leistungsfaktor auf der Basis von Informationen berechnet, die sich auf einen Lastwiderstandswert (R_S) und einen Lastinduktivitätswert (L_S) beziehen, wobei der Lastwiderstandswert (R_S) den Realteil bildet und der Lastinduktivitätswert (L_S) den komplexen Teil einer komplexen Lastimpedanz bildet.

13. Induktionsherd nach einem der vorhergehenden Ansprüche, wobei die Steuereinheit (11) so konfiguriert ist, dass sie den Leistungsfaktor auf der Basis der folgenden Formel berechnet:

$$\cos\varphi = \frac{R_S}{\sqrt{R_S{}^2 + \left(\omega_{av} L_S - \frac{1}{\omega_{av}{}^2\, C_{res}{}^2}\right)^2}}$$

wobei:

R_S der Lastwiderstandswert ist;
L_S der Lastinduktivitätswert ist;
ω_{av} ein gemittelter Frequenzwert ist; und
C_{res} der Kapazitätswert des Kondensators ist, der in dem Schwingkreis enthalten ist.

14. Induktionsherd nach einem der vorhergehenden Ansprüche, der keinen Stromwandler, der mit der Induktionsspule (6) elektrisch gekoppelt ist, umfasst, wobei Informationen bezüglich eines Spitzenwerts und eines Leistungsfaktors des elektrischen Stroms, der durch die Induktionsspule bereitgestellt wird, durch einen Algorithmus bereitgestellt werden, der die ersten und zweiten Informationen berücksichtigt.

15. Verfahren zum Betreiben eines Induktionsherds, wobei der Induktionsherd eine Schaltungsanordnung (1a) umfasst, um wenigstens eine Induktionsspule (6) mit Leistung zu versorgen, wobei die Schaltungsanordnung (1a) einen Leistungsschaltungsabschnitt (7) mit wenigstens einem Schaltelement (4, 5), der ausgelegt ist, gepulste elektrische Leistung für die Induktionsspule (6) bereitzustellen, und einen Schwingkreisabschnitt (9) umfasst, wobei die Induktionsspule (6) mit dem Leistungsschaltungsabschnitt (7) und dem Schwingkreisabschnitt (9) elektrisch gekoppelt ist, wobei der Induktionsherd eine Steuereinheit (11) umfasst, die die folgenden Schritte ausführt:

- Erhalten erster Informationen, die einer ersten Spannung (V_m) zugeordnet sind, die bei dem Leistungsschaltungsabschnitt (7) bereitgestellt wird;
- Erhalten zweiter Informationen, die einer zweiten Spannung (V_C) zugeordnet sind, die dem Schwingkreisabschnitt (9) zugeordnet ist;
- Berechnen von Informationen bezüglich eines Spitzenwerts und eines Leistungsfaktors des elektrischen Stroms, der durch die Induktionsspule bereitgestellt wird, auf der Basis der erhaltenen ersten und zweiten Informationen.

Revendications

1. Plaque de cuisson à induction comprenant un circuit (1a) pour alimenter au moins une bobine d’induction (6), le circuit (1a) comprenant une partie de circuit de puissance (7) avec au moins un élément de commutation (4, 5) adapté pour fournir une puissance électrique pulsée à ladite bobine d’induction (6) et une partie de circuit oscillant (9), ladite bobine d’induction (6) étant couplée électriquement avec ladite partie de circuit de puissance (7) et ladite partie de circuit oscillant (9), où
ladite plaque de cuisson à induction comprend une entité de commande (10), la plaque de cuisson à induction étant **caractérisée en ce que** ladite entité de commande (10) est configurée pour recevoir des premières informations corrélées à une première tension appliquée à ladite partie de circuit de puissance (7) et des secondes informations corrélées à une seconde tension appliquée à ladite partie de circuit oscillant (9), ladite entité de commande (10) étant également configurée pour calculer des informations sur une valeur de crête et un facteur de puissance du

courant électrique fourni par ladite bobine à induction (6) sur la base desdites premières et secondes informations reçues.

2. Plaque de cuisson à induction selon la revendication 1, dans laquelle lesdites premières informations sont indicatives d'une tension (V_m) pourvue à un nœud de circuit (7a) situé entre une paire d'éléments de commutation (4, 5).

3. Plaque de cuisson à induction selon la revendication 1 ou la revendication 2, dans laquelle lesdites premières informations sont calculées en prenant en compte des informations relatives à la tension secteur redressée (V_{main_s}) et des informations de facteur d'utilisation (duty).

4. Plaque de cuisson à induction selon l'une quelconque des revendications précédentes, dans laquelle lesdites premières informations sont calculées sur la base de la formule suivante :

$$V_m = \frac{2.V_{MAIN\_S}}{\pi}.\sin(\pi.duty)$$

où

V_{MAIN_S} est la valeur de crête de la tension secteur redressée ; et
duty désigne les informations relatives au facteur d'utilisation.

5. Plaque de cuisson à induction selon l'une quelconque des revendications précédentes, dans laquelle lesdites secondes informations sont indicatives d'une tension (V_c) fournie à un nœud de circuit (9a) situé entre une paire de condensateurs ($C_{res,1}$, $C_{res,2}$) inclus dans ladite partie de circuit oscillant (9).

6. Plaque de cuisson à induction selon l'une quelconque des revendications précédentes, dans laquelle lesdites secondes informations sont obtenues en utilisant une partie de circuit de détection comprenant un diviseur de tension (11).

7. Plaque de cuisson à induction selon la revendication 5 ou la revendication 6, dans laquelle lesdites secondes informations sont obtenues par échantillonnage de la tension (V_c) à un nœud de circuit (9a) de ladite partie de circuit oscillant (9), spécifiquement par échantillonnage de la tension (V_c) à un nœud de circuit (9a) situé entre une paire de condensateurs ($C_{res,1}$, $C_{res,2}$) compris dans ladite partie de circuit oscillant (9).

8. Plaque de cuisson à induction selon l'une quelconque des revendications précédentes, dans laquelle lesdites secondes informations comprennent des informations concernant les valeurs maximale et minimale de la tension (V_c) à un nœud de circuit (9a) situé entre une paire de condensateurs ($C_{res,1}$, $C_{res,2}$) inclus dans ladite partie de circuit oscillant (9).

9. Plaque de cuisson à induction selon l'une quelconque des revendications précédentes, dans laquelle l'entité de commande (11) est configurée pour calculer la valeur de crête du courant électrique fourni par ladite bobine d'induction (6) sur la base de la formule suivante :

$$I_C = 2\pi f(V_{C,max} - V_{C,min})C_{res,2}$$

où :

f est la fréquence du courant alternatif fourni à la bobine d'induction ;
$V_{C,max}$ est la valeur maximale de la tension fournie à un nœud entre une paire de condensateurs inclus dans ledit circuit oscillant ;
$V_{C,min}$ est la valeur minimale de la tension fournie à un nœud entre une paire de condensateurs inclus dans ledit circuit oscillant ; et
$C_{res,2}$ est la valeur de condensateur d'un condensateur à résonance inclus dans ledit circuit oscillant.

10. Plaque de cuisson à induction selon l'une quelconque des revendications précédentes, dans laquelle l'entité de commande (11) est configurée pour calculer le facteur de puissance sur la base de deux, ou davantage, valeurs de premières informations et de deux, ou davantage, valeurs de secondes informations, où les deux, ou davantage, valeurs de premières et secondes informations sont obtenues en attaquant la bobine d'induction (6) à différentes fréquences.

11. Plaque de cuisson à induction selon l'une quelconque des revendications précédentes, dans laquelle l'entité de commande (11) est configurée pour calculer le facteur de puissance sur la base d'une valeur de fréquence moyennée, ladite valeur de fréquence moyennée étant obtenue en calculant la moyenne arithmétique de deux valeurs de fréquence, ou davantage.

12. Plaque de cuisson à induction selon l'une quelconque des revendications précédentes, dans laquelle l'entité de commande (11) est configurée pour calculer le facteur de puissance sur la base d'informations concernant une valeur de résistance de charge (R_S) et une valeur d'inductance de charge (L_S), ladite valeur de résistance de charge (R_S) constituant la partie réelle et ladite valeur d'inductance de charge (L_S) constituant la partie complexe d'une impédance de charge complexe.

13. Plaque de cuisson à induction selon l'une quelconque des revendications précédentes, dans laquelle l'entité de commande (11) est configurée pour calculer le facteur de puissance sur la base de la formule suivante :

$$cos\varphi = \frac{R_S}{\sqrt{R_S^2 + (\omega_{av}L_S - \frac{1}{\omega_{av}^2 C_{res}^2})^2}}$$

où :

R_S est la valeur de résistance de charge ;
L_S est la valeur d'inductance de charge ;
ω_{av} est une valeur de fréquence moyennée ; et
C_{res} est la valeur de condensateur du condensateur inclus dans ledit circuit oscillant.

14. Plaque de cuisson à induction selon l'une quelconque des revendications précédentes, ne comprenant aucun transducteur de courant électriquement couplé à la bobine d'induction (6), où des informations concernant une valeur de crête et un facteur de puissance du courant électrique fourni par ladite bobine d'induction sont fournies par un algorithme considérant lesdites premières et secondes informations.

15. Procédé de fonctionnement d'une plaque de cuisson à induction, la plaque de cuisson à induction comprenant un circuit (1a) pour alimenter au moins une bobine d'induction (6), le circuit (1a) comprenant une partie de circuit de puissance (7) avec au moins un élément de commutation (4, 5) adapté pour fournir une puissance électrique pulsée à ladite bobine d'induction (6) et une partie de circuit oscillant (9), ladite bobine d'induction étant couplée électriquement avec ladite partie de circuit de puissance (7) et ladite partie de circuit oscillant (9), où ladite plaque de cuisson à induction comprend une entité de commande (11) exécutant les étapes suivantes :

- recevoir des premières informations corrélées à une première tension (V_m) fournie à ladite partie de circuit de puissance (7) ;
- recevoir des secondes informations corrélées à une seconde tension (V_c) corrélée à ladite partie de circuit oscillant (9) ;
- calculer des informations concernant une valeur de crête et un facteur de puissance du courant électrique fourni par ladite bobine d'induction sur la base desdites premières et secondes informations reçues.trg873644

FIG 1

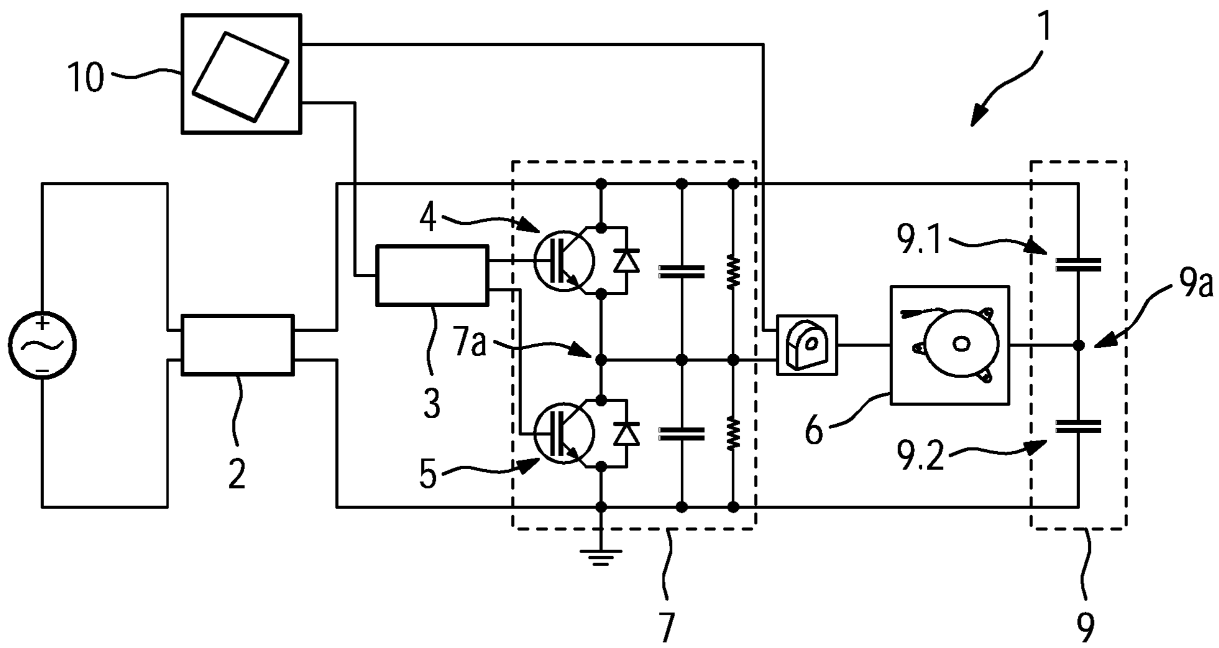


FIG 2

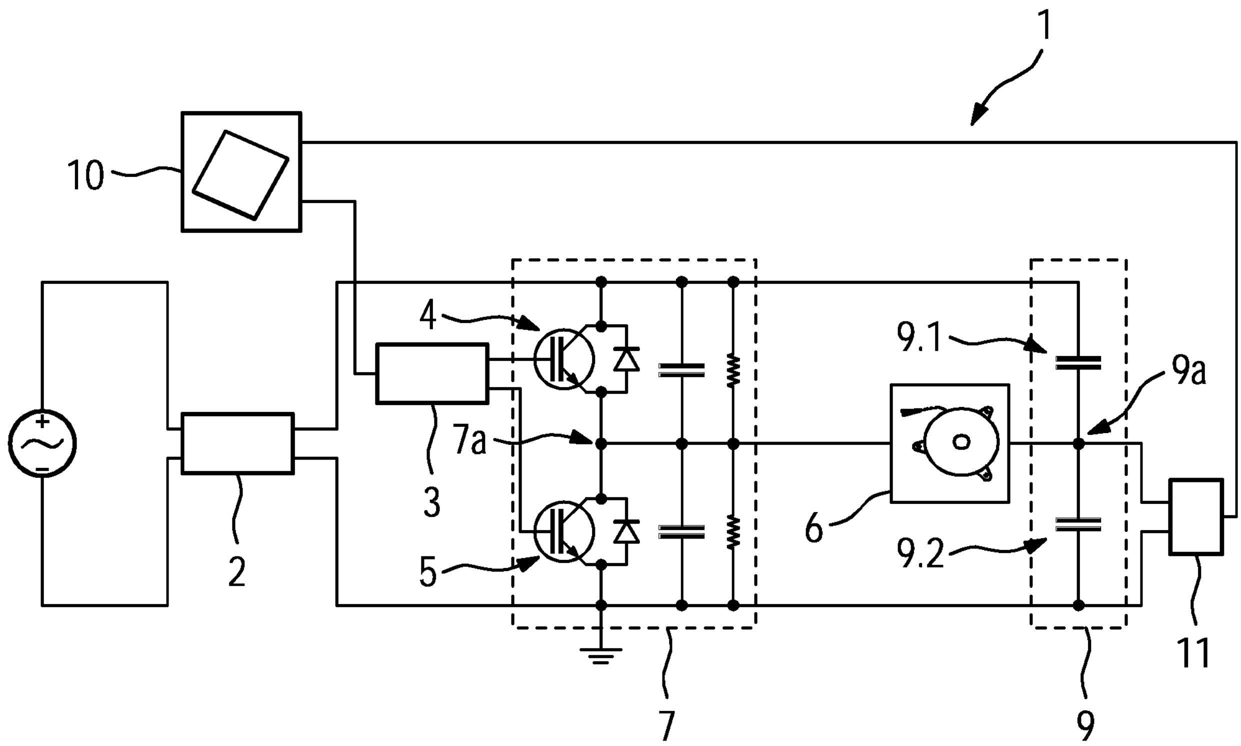
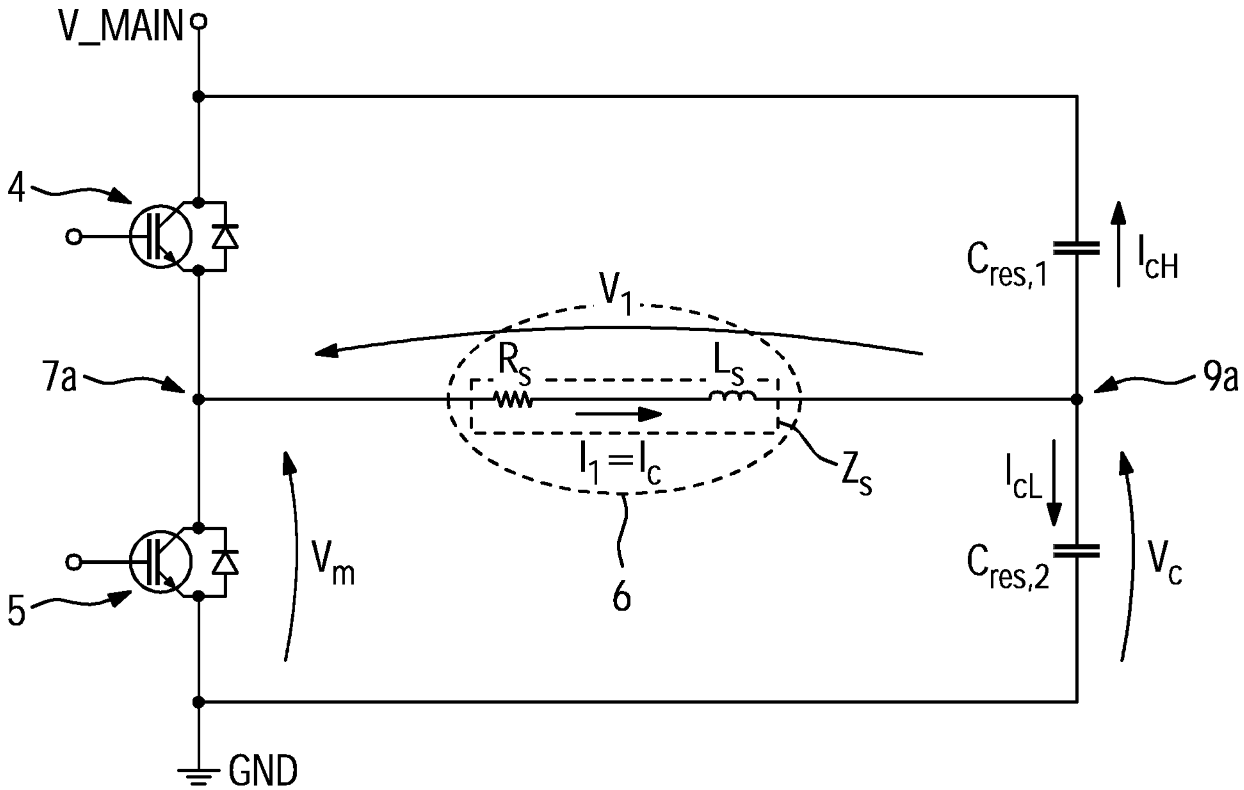


FIG 3



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