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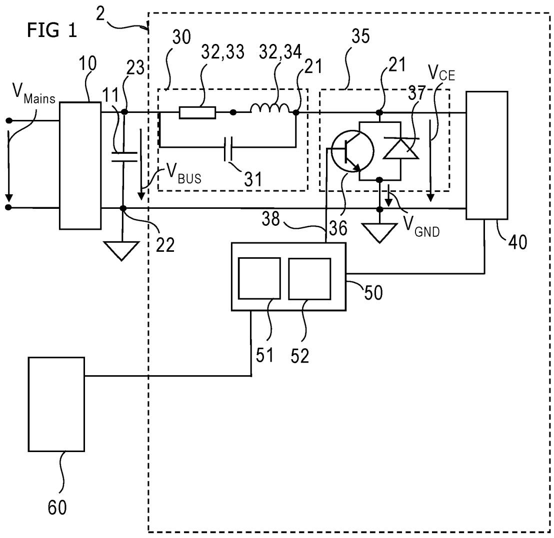
(54) INDUCTION HEATING UNIT, INDUCTION COOKING DEVICE, AND METHOD FOR OPERATING AN INDUCTION HEATING UNIT

(57) The invention relates to an induction heating unit (1), comprising at least one resonant tank (30) with at least one induction heating element (32, 33), a power requesting unit (60) for requesting a power (PR) of the at least one induction heating element (32), a driving unit (52) for driving the resonant tank (30), in particular by oscillating the resonant tank (30) by means of a switching element (35), by a driving signal comprising a series of subsequent sequences for generating a heating power (PH), each sequence comprising a first subsequence (S1) with a first alternating signal and with a first subsequence duration (D1), causing an activation of the resonant tank (30) with a predetermined power (PM), a subsequent second subsequence (S2) with an at least essentially non-alternating signal and with a second subsequence duration (D2), causing a deactivation of the resonant tank (30) and a subsequent third subsequence (S3) with a second alternating signal and a with a third subsequence duration (D3), causing an activation of the resonant tank (30) with less than the predetermined power (PM), an induction cooking device and a corresponding method.

FIG 1



EP 4 002 955 A1

Description

[0001] The invention relates to an induction heating unit for a cooking device, in particular for an induction cooking device, more particularly for an induction hob, to a corresponding induction cooking device, and to a method for operating an induction heating unit.

[0002] For an induction heating unit for a cooking device, in particular for an induction hob, in order to have a power delivery that is as much lossless as possible at a high level of power, the electric components in the induction heating unit are chosen to resonate at a frequency corresponding to high level of power.

[0003] However, this has the drawback in the fact that is not possible to resonate at low levels of power with acceptable losses. Hence, a pulsed power mode might be implemented with a period of order of ten of seconds in which the induction heating unit operates at a minimum continuous power for a part of the period as active part and stays off for the other part of the period as non-active part.

[0004] In this way, the average power delivered to a cookware can be less than the minimum continuous heating power, but a possible disadvantage of this approach is that the cooking experience might be poor as food can become overcooked in the active part and undercooked in the non-active part.

[0005] The object is solved in particular by an induction heating unit according to claim 1 and by a cooking device according to claim 13 as well the method according to claim 14. Improvements are provided in the dependent claims.

[0006] The invention relates in particular to an induction heating unit for a cooking device, in particular for an induction cooking device, more particularly for an induction hob, comprising

- at least one resonant tank with at least one induction heating element,
- a power requesting unit for requesting a power of the at least one induction heating element,
- a driving unit for driving, in particular in at least one operating mode, the resonant tank, in particular by oscillating the resonant tank by means of a switching element (or: switching unit), by a driving signal comprising a series of subsequent sequences for generating a heating power, each sequence comprising
    - a first subsequence with a first alternating signal and with a first subsequence duration, causing an activation of the resonant tank with a predetermined power,
    - a subsequent second subsequence with an at least essentially non-alternating signal and with a second subsequence duration, causing a deactivation of the resonant tank and
    - a subsequent third subsequence with a second alternating signal and a third subsequence duration, causing an activation of the resonant tank with less than the predetermined power.

[0007] Hence, low power can be delivered smoothly by an induction heating unit for a cooking device, in particular for an induction cooking device, more particularly for an induction hob. On the other hand, in particular, noise and/or thermal losses can be avoided or at least reduced by the repeated activation and deactivation of the resonant tank according to the invention.

[0008] In particular embodiments, the heating power is generated corresponding or at least essentially equal to or in a predetermined relation to the or a requested power.

[0009] In particular embodiments, the driving signal toggles and/or is configured to toggle, in particular in or during one, two, at least one, at least two or each subsequence(s), between at least one first driving state, in particular resulting in or effecting a partly or gradually closed state or in an at least essentially closed state of the switching element, and at least one second driving state, in particular resulting in or effecting an opened or in an at least essentially opened state of the switching element, preferably with a first, second and/or third drive frequency.

[0010] In particular, the first driving state is determined by a first driving signal parameter, preferably by a first driving signal voltage or by a first driving signal current. In particular, the second driving state is determined by a second driving signal parameter, preferably by a second driving signal voltage or by a second driving signal current.

[0011] In particular, the first driving state and/or the second driving state vary between the first, the second and the third subsequence.

[0012] In particular, the first driving signal parameter and/or the second driving signal parameter vary between the first, the second and/or the third subsequence.

[0013] In particular, the first driving state and/or the second driving state of the third subsequence vary compared to the first driving states and/or the second driving states of the first subsequence and the second subsequence. In particular, the first driving state and/or the second driving state of the first subsequence is/are at least essentially identical to the first driving state and/or the second driving state of the second subsequence.

[0014] In particular, the first driving signal parameter and/or the second driving signal parameter of the third subsequence vary compared to the first driving signal parameters and/or the second driving signal parameters of the first subsequence and the second subsequence. In particular, the first driving signal parameter and/or the second driving signal parameter of the first subsequence is/are at least essentially identical to the first driving signal parameter and/or the second driving signal parameter of the second subsequence.

[0015] In particular, the first driving signal voltage and/or the second driving signal voltage of the third subsequence is lower or higher than the first driving signal voltage and/or the second driving signal voltage of the first subsequence and/or the second subsequence.

[0016] More in particular, the first driving signal voltage of the third subsequence is or can be lower than the first driving signal voltage of the first subsequence and/or the first driving signal voltage of the second subsequence.

[0017] More in particular, the second driving signal voltage of the third subsequence is or can be the same voltage or at least essentially the same voltage as the second driving signal voltage of the first subsequence and/or the second driving signal voltage of the second subsequence.

[0018] In particular, the first driving signal voltage and/or the second driving signal voltage are (or: correspond to) gate voltages of the switching element. As an example, the first driving signal voltage can be a voltage which closes the switching element, in particular drives it to a closed state, whereas the second driving signal voltage can be a voltage which opens the switching element or leaves it open, in particular drives it to an opened state.

[0019] In particular embodiments, the switching element is or comprises a transistor, more in particular an insulated gate bipolar transistor, IGBT.

[0020] Hence, in particular, noise at turn-on of the induction heating element and/or noise on activation of the resonant tank can be further reduced. In particular, the switching element is gradually closed by gradually, preferably linearly or at least essentially linearly, increasing the first driving signal voltage, preferably from a predetermined first voltage value to a predetermined second voltage value. More in particular, the switching element is or can be gradually closed by gradually increasing the first driving signal voltage over a predetermined number of pulses or periods of the first driving signal.

[0021] In particular embodiments, in at least one operating mode, the first subsequence duration and the second subsequence duration are selected such that a variation and/or the reduction of the heating power is in a predetermined range, in particular such that the variation and/or the reduction of the power in relation to the requested power is more than a predetermined minimum variation and/or reduction and less than a predetermined maximum variation and/or reduction. By this, preferably, the cooking result can be improved, as the corresponding variation and/or reduction of the cooking temperature can be limited, in particular while still avoiding or at least reducing noise and/or thermal losses due to the repeated activation and deactivation of the resonant tank.

[0022] In particular, the minimum variation and/or reduction of the power can be 3%, more in particular 5%. In particular, the maximum variation and/or reduction of the power can be 30%, more in particular 20%, more in particular 10%.

[0023] In particular, the heating power is generated at least essentially corresponding to the requested power.

[0024] In a particular embodiment, as an example, for a requested and/or continuous power of 1000W, the minimum reduction of the heating power can be 3%, corresponding to a power reduction of at least 30W, i. e. to a power of 970W or less, whereas the maximum reduction of the heating power can be 30%, corresponding to a power reduction of 300W or less, i. e. to a power of 700W or more. More in particular, for a power reduction between 3% and 30%, for an assumed requested and/or continuous power of 1000W, the reduction of the power will or can result in a power between 700W and 1000W.

[0025] In particular, a subsequent sequence is a sequence which immediately follows a previous sequence, so that more in particular the first sequence is immediately followed by the second sequence and/or the second sequence is immediately followed by the third sequence and/or the third sequence is immediately followed by the first sequence.

[0026] In embodiments, at least one resonant tank is supplied with power by a pulsed supply signal, in particular a pulsed DC supply signal, more in particular a pulsed DC bus supply signal,

[0027] In particular, a pulsed DC supply signal comprises DC pulses, wherein a DC pulse is a rectified half-period of an external AC supply signal, in particular of an AC supply signal with in input voltage of 110 to 240 V and a frequency of 50 to 60 Hz. In particular, the rectified AC supply signal is smoothened by a filter unit, in particular a DC capacitor. As an example, a DC pulse may have a pulse length between 5ms and 20 ms, in particular between 8ms and 10ms.

[0028] Especially, the heating power is an effective heating power and/or an average heating power, in particular averaged over one, at least one, two, at least two, ten or at least ten periods of an AC supply signal and/or averaged over a period of 20ms, at least 20ms, 40ms, at least 40ms, 100ms, at least 100ms, 200ms or at least 200ms, more in particular dependent on the AC supply signal frequency.

[0029] In particular embodiments, the heating power is or can be an effective heating power and/or an average heating power, in particular averaged over a period of 1 to 10 DC pulses. In embodiments, 1 to 10, more in particular, 2 to 9, DC pulses over a period of 10 DC pulses contribute or can contribute to the average of power.

[0030] In particular embodiments, one or more (1 to 10) DC pulses over a period of 10 DC pulses contribute or at least can contribute to the average of power, in particular to the effective heating power and/or the average heating power.

[0031] In particular embodiments, the DC pulse duration depends on the AC voltage frequency. Preferably, the AC voltage frequency is 50Hz or 60Hz.

[0032] In particular embodiments, for a frequency of 50Hz, the period is 20ms and a DC pulse duration is 10ms, so that when the heating power is an effective heating power and/or an average heating power averaged over five periods, it is averaged over 100ms.

[0033] In particular embodiments, for a frequency of

60Hz, the period is about 16.6ms and a DC pulse duration is about 8.3ms, so that when the heating power is an effective heating power and/or an average heating power averaged over five periods, it is averaged over about 83ms.

[0034] The actual heating power or instantaneous heating power can vary, for example due to the oscillation of the AC supply signal. Hence, the minimum duration for measuring an effective heating power can especially be at least one period or at least two periods, in particular 1 to 10 periods of the AC supply signal.

[0035] The heating power is in particular an electrical power consumed by the induction heating unit and/or at least essentially transferred to a cooking vessel.

[0036] Especially, the heating power can vary in a predetermined range between a predetermined minimum variation and a predetermined maximum variation.

[0037] In embodiments, the actual or instantaneous heating power varies between a predetermined power, in particular a minimum continuous heating power during the first subsequence and at least essentially a zero power during the second subsequence as a power difference.

[0038] In embodiments, the minimum continuous heating power is the minimum continuous heating power where the losses, in particular thermal losses in the induction heating unit, more in particular in the switching element, are below a predetermined value, in particular below 20%.

[0039] In particular, the switching element is or at least can be a switching unit.

[0040] The resonant tank in particular has a resonance frequency which is determined by the capacitive element and the inductive element which is also influenced by the coupling with a cooking vessel arranged on the induction heating unit.

[0041] In embodiments, the first subsequence with first alternating signals starts at a first starting time of a first DC pulse and ends at a second starting time of an, in particular subsequent, second DC pulse, with a first subsequence duration, a first drive frequency, a first duty cycle and/or a first Ton time.

[0042] In general, a Ton time can also be expressed as an ON time. A Ton time is preferably the pulse duration of a signal or the duration in which a signal is active.

[0043] Preferably, the switching element is closed and/or in a closed state during the ON time or Ton time. Preferably, the switching element is opened and/or in an opened state during the OFF time or Toff time.

[0044] In general, a Toff time can also be expressed as an OFF time. A Toff time is preferably the duration between two pulses of a signal or the duration in which a signal is inactive.

[0045] In particular, the first subsequence duration is determined by or at least essentially equal to the duration of the first DC pulse or determined by or at least essentially equal to the added duration of multiple DC pulses.

[0046] In embodiments, the second subsequence with non-alternating signals starts at the second starting time of the/a second DC pulse and ends at an activation start time, at a third subsequence duration before a third starting time of a third DC pulse, in particular at a third subsequence duration between the second starting time of a second DC pulse and the third starting time of the DC third pulse, with a second subsequence duration, a second drive frequency of at least essentially zero, a second duty cycle of at least essentially zero and/or a second Ton time of at least essentially zero.

[0047] The second subsequence duration is preferably determined by the duration of the second DC pulse or equal to the added duration of multiple DC pulses, minus the third subsequence duration.

[0048] In embodiments, the third subsequence with second alternating signals starts at an activation start time, a third subsequence duration before the third starting time of a third DC pulse, between a second starting time of a second DC pulse and a third starting time of the DC third pulse, and ends at the starting time of the third DC pulse, with a third drive frequency as well as duty cycles and/or a Ton time increasing from the third duty cycle or third Ton time to the first duty cycle or first Ton time.

[0049] In particular, the third subsequence duration is less than 30%, in particular less than 20%, more in particular equal to 10% or less than 10% of the DC pulse duration.

[0050] In embodiments, the first alternating signal is a pulse wave and/or comprises a, in particular constant, first drive pulse length, in particular Ton time and/or Toff time and/or a first duty cycle and/or first frequency, wherein the first alternating signal generates the predetermined power, that could be in particular the minimum continuous heating power by means of the resonant tank.

[0051] In particular, the first duty cycle causes an activation of the resonant tank with a predetermined heating power, for example a minimum continuous heating power, by generating an oscillation of the resonant tank.

[0052] If, however, the first Ton time and/or the first duty cycle would be further reduced, the switching losses are increased, as the switching is performed in the so called hard switching region, wherein an at least relatively large voltage is switched together with at least relatively large current.

[0053] In particular, the duty cycle is between 15% and 50%, more in particular between 20% and 40%, more in particular between 25% and 30%.

[0054] In particular, the pulse length is between 15% and 50%, more in particular between 20% and 40%, more in particular between 25% and 30% of the wavelength at the resonance frequency. In other words, for each period of the driving signal, the switching element is in a closed state only between 15% and 50%, more in particular between 20% and 40%, more in particular between 25% and 30% of the wavelength at the resonance frequency.

[0055] In embodiments, the at least essentially non-alternating signal with a second pulse length, a second duty cycle and a second frequency at least essentially deactivates or shuts off the resonant tank. In particular, the non-alternating signal is or can be a constant signal, which is more in particular constantly zero.

[0056] In embodiments, the second duty cycle causes a deactivation of the resonant tank, as due to the zero or at least short opening time based on the zero or at least short pulse length, a charging or discharging of the capacitive element and hence an activation of the resonant tank does not occur.

[0057] In particular, the second duty cycle is or can be between 0 and 1/10, more in particular between 0 and 1/30, more in particular between 0 and 1/100. In other words, for each period of the driving signal, the switching element is in a closed state only between 0 and 1/10, more in particular between 0 and 1/30, more in particular between 0 and 1/100 of each switching period.

[0058] In particular, the pulse length is between 0 and 1/10, more in particular between 0 and 1/30, more in particular between 0 and 1/100 of the wavelength at the resonance frequency. In other words, for each period of the driving signal, the switching element is in a closed state only between 1/1000 and 1/10, more in particular between 1/1000 and 1/100, more in particular between 2/1000 and 20/1000 of the wavelength at the resonance frequency.

[0059] As an example, for a resonance frequency of 20kHz, the period or wavelength of the driving signal is or can be 50ns. Hence, for example, the pulse length and/or the duration wherein the switching element is in a closed state, in particular during the second duty cycle, is or can be between 0ns and 5ns. Correspondingly, for this example of the second duty cycle, for each period, the switching element is in an opened state between 45ns and 50ns. In particular embodiments, the switching element is or can be not driven into the closed state at all during the second duty cycle.

[0060] In particular, the wavelength at the resonance frequency is the inverse value of the resonance frequency.

[0061] In embodiments, the second alternating signal comprises increasing third drive pulse lengths, in particular increasing third Ton times, increasing third duty cycles and/or an, in particular at least essentially constant, third drive frequency and/or generates a heating power starting from less than to at least essentially equal to the minimum continuous power in the resonant tank.

[0062] In embodiments, the third drive pulse lengths and/or third duty cycles and/or an Ton times are in particular increasing linearly and/or stepwise from a first third drive pulse length and/or a first third duty cycle and/or a first third drive Ton time on the one hand to a second third drive pulse length and/or a second third duty cycle and/or a second third drive Ton time.

[0063] In particular, the second third duty cycle or second third Ton time is at least essentially identical to the first duty cycle or the first Ton time.

[0064] In particular, the first and/or third drive frequency is/are or can be different from the resonance frequency of the resonant tank. In particular, the drive frequency depends on the power request and/or on the requested power. More in particular, at minimum continuous power or at minimum not pulsed power, the drive frequency is not at resonance and/or the drive frequency is not the resonance frequency of the resonant tank.

[0065] In particular, a resonance detection means detects an oscillation duration of the resonance tank, in particular by determining a dropping of the voltage in the resonance tank.

[0066] In particular, a Toff time of a signal is obtained by the difference of the oscillation duration or oscillation period and/or of the inverse of the drive frequency of the signal on the one hand and of the Ton time of the signal on the other hand.

[0067] In particular, the first duty cycle and/or the first Ton time generate the minimum continuous heating power, wherein the losses, in particular thermal losses in the induction heating unit, more in particular in the switching element, are below a predetermined value, in particular below 20%.

[0068] In particular, the first drive frequency and/or the second third drive frequency at least essentially are the same during the first subsequence and/or at the end of the third subsequence.

[0069] In particular, the third duty cycles and the third Ton times generate a heating power starting from smaller than to at least essentially equal to the minimum continuous heating power, in particular from less than 1/10 of the minimum possible heating power to at least essentially the minimum possible heating power.

[0070] In particular, the third duty cycles cause a gentle activation of the resonant tank with starting from less than to equal to the minimum continuous drive pulse length, by generating an oscillation of the resonant tank.

[0071] In particular, the first duty cycle is between 15% and 50%, more in particular between 20% and 40%, more in particular between 25% and 35%.

[0072] In particular, the third duty cycles are increasing from at least 1% to below 50%, more in particular from 2% to below 40%, more in particular from 3% to below 35%.

[0073] In particular, the third drive pulse lengths increase stepwise within the third subsequence duration as predetermined switch-on time from the first third drive pulse length as start fraction of the minimum drive pulse length to the first drive pulse length as minimum drive pulse length.

[0074] As an example, the third drive pulse lengths might increase from 1μs to 11 μs by 0.5μs every 100μs, so that, after 2ms, a minimum continuous drive pulse length is obtained.

[0075] In other words, for each period of the second alternating signal, the switching element is preferably in a closed state from below 10% to 100% of the minimum pulse length.

[0076] In particular, the third drive pulse lengths increase from at least 9% to 100% of the minimum pulse length. In other words, for each period of the second alternating signal, the switching element is in a closed state from starting form at least 9% to 100% of the minimum pulse length.

[0077] In particular, a DC pulse detection means detects the minimum of the DC pulses and hence a DC pulse duration.

[0078] In particular, the activation start time is a switch-on time start time for the third duty cycles which is determined based on the end of the previous DC pulse and the difference of the DC pulse duration and the third subsequence duration as switch-on time or activation time.

[0079] In particular, a sequence duration detection means detects a sequence duration as a number of sequence DC pulses by stepwise increasing a number of DC pulses until the variation of the heating power during a sequence is in the predetermined range.

[0080] In particular, a sequence duration setting means sets a sequence duration such that the variation of the heating power is in the predetermined range.

[0081] In particular, the number of DC pulses in a sequence determines the sequence duration, wherein the number of DC pulses in the first subsequence determines the first subsequence duration, wherein the number of DC pulses in the second subsequence determines the second subsequence duration.

[0082] In particular, the first subsequence duration and the second subsequence duration are determined such that a required power is obtained as heating power.

[0083] In particular, the number of DC pulses in the first subsequence and the number of DC pulses in the second subsequence are determined such that a required power is obtained.

[0084] In particular, the number of DC pulses in the first subsequence is obtained by multiplying the number of DC pulses in the sequence with the quotient of the requested power and the minimum continuous power with, and, in particular, rounding up or down the result.

[0085] In particular, the heating unit comprises a power driving control unit for determining the ratio between the first and the second subsequence duration and/or for determining the first and the second subsequence duration determined based on a requested power level.

[0086] In particular, the predetermined power is the minimum continuous power and the requested power is lower than the predetermined power.

[0087] In particular, the minimum continuous power is or can be the minimum power, preferably in continuous operation, for which the switching losses for generating the heating power and/or the thermal losses for generating the heating power do not exceed a predetermined value.

[0088] In particular, the switching element is a quasi-resonant switching element.

[0089] The resonant tank is in particular a quasi-resonant oscillation circuit or quasi-resonant tank.

[0090] A quasi-resonant oscillation circuit is in particular an oscillation circuit wherein the oscillation circuit can, for excitation, only be switchably connected to one of the voltage nodes. In other words, preferably, only a single switching element, in particular quasi-resonant switching element, exists which can connect the quasi-resonant tank or quasi-resonant oscillation circuit only to a single voltage.

[0091] In particular, the resonant tank comprises or can comprise a capacitive and an inductive element, in particular for oscillating the resonant tank.

[0092] In particular, the resonant tank with a capacity as C as well as an inductance as L corresponds with or has a resonance frequency F1, which is at least essentially

$$F1 = 1/(2*pi*sqrt(L*C)).$$

[0093] Hence, for an excitation signal, the period P1 must be at least essentially

$$P1 = 2*pi*sqrt(L*C)$$

and correspondingly, the length of a pulse must be at least approximately or in the range of

$$L3 = pi*sqrt(L*C),$$

if the resonant tank shall be excitated. The resonant tank is switched off, if the pulse length is much smaller than the resonance pulse length, in particular if it is smaller than 1/100 of the resonance pulse length.

[0094] The invention also relates to an induction heating device, comprising

- at least one, two, at least two, four, at least four, six or at least six Induction heating units according to the invention,
    - a rectifying means for rectifying an external AC power supply signal into a pulsed bus DC supply signal comprising a series of DC pulses for supplying at least one, two, at least two, four, at least four, six or at least six Induction heating units according to the invention,
- a power level defining unit, in particular a user interface, for determining at least one requested power level of the induction heating device and
- at least one detecting unit for detecting starting times of the DC pulses.

[0095] The invention also relates to method for operating an induction heating unit, in particular according to the invention and/or in at least one operating mode, the method comprising

- by a power requesting unit, requesting a power of the at least one induction heating element,
- by a driving unit, driving the resonant tank, in particular oscillating the resonant tank by means of a switching element, by a driving signal comprising a series of subsequent sequences for generating a heating power, each sequence comprising

  ◦ a first subsequence with a first alternating signal and with a first subsequence duration, causing an activation of the resonant tank with a predetermined power,
  ◦ a subsequent second subsequence with an at least essentially non-alternating signal and with a second subsequence duration, causing a deactivation of the resonant tank and
  ◦ a subsequent third subsequence with a second alternating signal, causing an activation of the resonant tank with less than the predetermined power.

[0096] In embodiments, the method for operating an induction heating unit further comprises by a power driving control unit, determining the ratio between the first and the second duration and/or determining the first and the second duration determined based on a requested power level, wherein in particular the predetermined power is the minimum continuous power and the requested power is lower than the predetermined power (PM).

[0097] The present invention will be described in further detail with reference to the drawings, in which

FIG 1 shows an induction heating unit according to an embodiment of the present invention,

FIG 2 shows an induction cooking device according to an embodiment of the present invention,

FIG 3 shows an induction cooking device according to an embodiment of the present invention,

FIG 4 shows DC pulses according to an embodiment of the present invention and

FIG 5 shows DC pulses and a driving signal according to an embodiment of the present invention.

[0098] FIG. 1 shows an induction heating unit 1 according to an embodiment of the present invention.

[0099] The induction heating unit 1 comprises a resonant tank 30 with an induction heating element 32, 33.

[0100] The induction heating unit 1 further comprises a power requesting unit 60 for requesting a power PR of the induction heating element 32.

[0101] The induction heating unit 1 further comprises a driving unit 52 for driving the resonant tank 30, by oscillating the resonant tank 30 by means of a switching element 35, by a driving signal comprising a series of subsequent sequences for generating a heating power PH, in particular in at least one operating mode.

[0102] Each sequence comprises

◦ a first subsequence S1 with a first alternating signal and with a first subsequence duration D1, causing an activation of the resonant tank 30 with a predetermined power PM,
◦ a subsequent second subsequence S2 with an at least essentially non-alternating signal and with a second subsequence duration D2, causing a deactivation of the resonant tank 30 and
◦ a subsequent third subsequence S3 with a second alternating signal, causing an activation of the resonant tank 30 with less than the predetermined power PM.

[0103] The heating power PH is generated corresponding to the requested power PR.

[0104] In particular, the driving signal 38 toggles between at least one first driving state resulting in an closed state or gradually closed state of the switching element and at least one second driving state resulting in an opened state of the switching element.

[0105] In particular, the first driving state is determined by a first driving signal parameter, preferably by a first driving signal voltage or by a first driving signal current. In particular, the second driving state is determined by a second driving signal parameter, preferably by a second driving signal voltage or by a second driving signal current.

[0106] In particular, the first driving state and/or the second driving state vary between the first, the second and the third subsequence.

[0107] In the embodiment, preferably the first driving state and/or the second driving state of the third subsequence vary compared to the first driving states and/or the second driving states of the first subsequence and/or the second subsequence.

[0108] In the embodiment, preferably the first driving signal parameter and/or the second driving signal parameter of the third subsequence vary compared to the first driving signal parameters and/or the second driving signal parameters of the first subsequence and/or the second subsequence.

[0109] In the embodiment, the first driving signal voltage and/or the second driving signal voltage of the third subsequence is lower or higher than the first driving signal voltage and/or the second driving signal voltage of the first subsequence and the second subsequence.

[0110] In the embodiment, the first driving signal voltage of the third subsequence is lower than the first driving signal voltage of the first subsequence and of the second subsequence.

[0111] In the embodiment, the first driving signal voltage and the second driving signal voltage are (or: correspond to) gate voltages of the switching element.

[0112] In the embodiment, the switching element is or comprises a transistor, in particular an insulated gate bipolar transistor, IGBT.

[0113] Hence, noise at turn-on of the induction heating element and noise on activation of the resonant tank can be further reduced. In particular, the switching element is or can be gradually closed by gradually, preferably linearly or at least essentially linearly, increasing the first driving signal voltage, preferably from a predetermined first voltage value to a predetermined second voltage value.

[0114] In at least one operating mode, a first subsequence duration D1 and a second subsequence duration D2 are selected such that a variation of the heating power PH is in a predetermined range.

[0115] The variation of the power PH in relation to the requested power PR is more than a predetermined minimum variation and less than a predetermined maximum variation.

[0116] The minimum variation is, in an embodiment, 3%, in particular 5%. The maximum variation is, in an embodiment, 30%, in particular 20%, more in particular 10%.

[0117] As an example, for a requested and/or continuous power of 1000W, the minimum reduction of the heating power can be 3%, corresponding to a power reduction of at least 30W, i. e. to a power of 970W or less, whereas the maximum reduction of the heating power can be 30%, corresponding to a power reduction of 300W or less, i. e. to a power of 700W or more.

[0118] As an example, for a power reduction between 3% and 30%, for an assumed requested and/or continuous power of 1000W, the reduction of the power will or can result in a power value between 700W and 1000W.

[0119] A subsequent sequence is a sequence which immediately follows a previous sequence. In particular, the first sequence is immediately followed by the second sequence, the second sequence is immediately followed by the third sequence and the third sequence is immediately followed by the first sequence.

[0120] The resonant tank 30 is supplied with power by a pulsed supply signal, in particular a pulsed DC supply signal, more in particular a pulsed DC bus supply signal 21, 22.

[0121] A pulsed DC supply signal comprises DC pulses, wherein a DC pulse is a rectified half-period of an external AC supply signal, in particular of an AC supply signal with in input voltage of 110 to 240 V and a frequency of 50 to 60 Hz, wherein in particular the rectified AC supply signal is smoothened by a filter unit, in particular a DC capacitor.

[0122] The heating power PH is an effective heating power and/or an average heating power, in particular averaged over one, at least one, two, at least two, ten or at least ten periods of an AC supply signal and/or averaged over a period of 20ms, at least 20ms, 40ms, at least 40ms, 100ms, at least 100ms, 200ms or at least 200ms, more in particular dependent on the AC supply signal frequency.

[0123] In particular embodiments, the heating power is or can be an effective heating power and/or an average heating power, in particular averaged over a period of 1 to 10 DC pulses. In embodiments, 1 to 10, more in particular, 2 to 9, DC pulses over a period of 10 DC pulses contribute or can contribute to the average of power.

[0124] In embodiments, one or more (1 to 10) DC pulses over a period of 10 DC pulses contribute or at least can contribute to the average of power, in particular to the effective heating power and/or the average heating power.

[0125] In particular embodiments, the DC pulse duration depends on the AC voltage frequency of the AC supply signal. Preferably, the AC voltage frequency is 50Hz or 60Hz.

[0126] In embodiments, for a frequency of 50Hz, the period is 20ms and a DC pulse duration is 10ms, so that when the heating power is an effective heating power and/or an average heating power averaged over five periods, it is averaged over 100ms.

[0127] In embodiments, for a frequency of 60Hz, the period is about 16.6ms and a DC pulse duration is about 8.3ms, so that when the heating power is an effective heating power and/or an average heating power averaged over five periods, it is averaged over about 83ms.

[0128] The actual heating power or instantaneous heating power varies, for example due to the oscillation of the AC supply signal. Hence, the minimum duration for measuring an effective heating power is at least one period or at least two periods of the AC supply signal.

[0129] The heating power PH is an electrical power consumed by the induction heating unit and/or at least essentially transferred to a cooking vessel.

[0130] The heating power varies in a predetermined range between a predetermined minimum variation and a predetermined maximum variation.

[0131] The actual or instantaneous heating power varies between a predetermined power, in particular a minimum continuous heating power PM during the first subsequence and at least essentially a zero power during the second subsequence by a power difference.

[0132] The minimum continuous heating power is the minimum continuous heating power where the losses, in particular thermal losses in the induction heating unit, more in particular in the switching element, are below a predetermined value, in particular below 20%.

[0133] The resonant tank has a resonance frequency which is determined by the capacitive element and the inductive element which is also influenced by the coupling with a cooking vessel arranged on the induction heating unit.

[0134] The first subsequence S1 with first alternating signals starts at a first starting time T1 of a first DC pulse P1 and ends at a second starting time T2 of an, in particular subsequent, second DC pulse P2, with a first subsequence duration D1, a first drive frequency, a first duty cycle C1 and/or a first Ton time.

[0135] The first subsequence duration D1 is determined by the duration of the first DC pulse P1 or determined by the added duration of multiple DC pulses.

[0136] The second subsequence S2 with non-alternating signals starts at the second starting time T2 of the second DC pulse P2 and ends at an activation start time T2a, at a third subsequence duration D3 before a third starting time T3 of the third DC pulse P3, in particular at a third subsequence duration D3 between the second starting time T2 of a second DC pulse P2 and the third starting time T3 of the DC third pulse P3.

[0137] The second subsequence S2 has a second subsequence duration D2, a second drive frequency of at least essentially zero, a second duty cycle of at least essentially zero C2 and a first Ton time of at least essentially zero.

[0138] The second subsequence duration D2 is determined by the duration of the second DC pulse P2 or equal to the added duration of multiple DC pulses, minus the third subsequence duration D3.

[0139] The third subsequence S3 with second alternating signals starts at an activation start time T2a, a third subsequence duration D3 before the third starting time T3 of a third DC pulse P3, between a second starting time T2 of a second DC pulse P2 and a third starting time T3 of the DC third pulse P3, and ends at the starting time T3 of the third DC pulse P3, with a third drive frequency as well as duty cycles and/or a Ton time increasing from the second duty cycle or second Ton time to the third duty cycle C3 or third Ton time.

[0140] The third subsequence duration D3 is less than 30%, in particular less than 20%, more in particular equal to 10% or less than 10% of the DC pulse duration.

[0141] The first alternating signal C1 is a pulse wave and/or comprises a, in particular constant, first drive pulse length, in particular Ton time and/or Toff time and/or a first duty cycle and/or first frequency.

[0142] The first alternating signal generates the predetermined power, in particular the minimum continuous heating power by means of the resonant tank 30.

[0143] The first duty cycle C1 causes an activation of the resonant tank 30 with a predetermined minimum continuous heating power PM, by generating an oscillation of the resonant tank 30.

[0144] If the first Ton time and/or the first duty cycle are further reduced, the switching losses are increased, as the switching is performed in the so called hard switching region, wherein an at least relatively large voltage is switched together with at least relatively large current.

[0145] The first duty cycle is between 15% and 50%, more in particular between 20% and 40%, more in particular between 25% and 30%.

[0146] The first pulse length is between 15% and 50%, more in particular between 20% and 40%, more in particular between 25% and 30% of the wavelength 2*pi*sqrt(L*C) at the resonance frequency 1/(2*pi*sqrt(L*C)). In other words, for each period of the driving signal, the switching element 35 is in a closed state only between 15% and 50%, more in particular between 20% and 40%, more in particular between 25% and 30% of the wavelength 2*pi*sqrt(L*C) at the resonance frequency 1/(2*pi*sqrt(L*C)).

[0147] The at least essentially non-alternating signal C2 with a second pulse length, a second duty cycle and a second frequency at least essentially deactivates or shuts off the resonant tank. In particular, the non-alternating signal C2 is a constant signal, which is more in particular constantly zero.

[0148] The second duty cycle C2 causes a deactivation of the resonant tank 30, as due to the zero or at least short opening time based on the zero or at least short pulse length, a charging for a series resonant tank or discharging for a parallel resonant tank of the capacitive element and hence an activation of the resonant tank does not occur.

[0149] The second duty cycle is between 0 and 1/10, more in particular between 0 and 1/30, more in particular between 0 and 1/100. In other words, for each period of the driving signal, the switching element 35 is in a closed state only between 0 and 1/10, more in particular between 0 and 1/30, more in particular between 0 and 1/100 of each switching period.

[0150] The pulse length is between 0 and 1/10, more in particular between 0 and 1/30, more in particular between 0 and 1/100 of the wavelength pi*sqrt(L*C) at the resonance frequency pi*sqrt(L*C). In other words, for each period of the driving signal, the switching element 35 is in a closed state only between 1/1000 and 1/10, more in particular between 1/1000 and 1/100, more in particular between 2/1000 and 20/1000 of the wavelength 2*pi*sqrt(L*C) at the resonance frequency 1/(2*pi*sqrt(L*C)).

[0151] The wavelength at the resonance frequency is the inverse value of the resonance frequency.

[0152] The second alternating signal C3 comprises increasing third drive pulse lengths, in particular increasing third Ton times, increasing third duty cycles and/or an, in particular at least essentially constant, third drive frequency.

[0153] The second alternating signal C3 generates a heating power starting from less than to at least essentially equal to the minimum continuous power in the resonant tank 30.

[0154] The third drive pulse lengths and/or third duty cycles and/or a Ton times are in particular increasing linearly and/or stepwise from a first third drive pulse length, a first third duty cycle and a first third drive Ton time on the one hand to a second third drive pulse length, a second third duty cycle and a second third drive Ton time.

[0155] The second third duty cycle C2 or second third Ton time is at least essentially identical to the first duty cycle C1 or the first Ton time.

[0156] The first and third drive frequency are at least essentially the resonance frequency of the resonant tank.

[0157] A resonance detection means detects an oscillation duration of the resonance tank, in particular by determining a dropping of the voltage in the resonance tank.

[0158] A Toff time is obtained by the difference of oscillation duration and/or the inverse of the drive frequency and the Ton time.

[0159] The first duty cycle C1 and the first Ton time generate the minimum continuous heating power, wherein the losses, in particular thermal losses in the induction heating unit, more in particular in the switching element, are below a predetermined value, in particular below 20%.

[0160] The first drive frequency and the second third drive frequency at least essentially are the same during the first subsequence and at the end of the third subsequence.

[0161] The third duty cycles C3 and the third Ton times generate a heating power starting from smaller than to at least essentially equal to the minimum continuous heating power, in particular from less than 1/10 of the minimum possible heating power to at least essentially the minimum possible heating power.

[0162] The third duty cycles C3 cause a gentle activation of the resonant tank 30 with starting from less than to equal to the minimum continuous drive pulse length PM, by generating an oscillation of the resonant tank 30.

[0163] The first duty cycle C1 is between 15% and 50%, more in particular between 20% and 40%, more in particular between 25% and 35%.

[0164] The third duty cycles C3 are increasing from at least 1% to below 50%, more in particular from 2% to below 40%, more in particular from 3% to below 35%.

[0165] The third drive pulse lengths increase stepwise within the third subsequence duration D3 as predetermined switch-on time from the first third drive pulse length as start fraction of the minimum drive pulse length to the first drive pulse length as minimum drive pulse length.

[0166] As an example, the third drive pulse lengths might increase from 1μs to 11 μs by 0.5μs every 100μs, so that, after 2ms, a minimum continuous drive pulse length is obtained.

[0167] In other words, for each period of the second alternating signal S3, the switching element 35 is in a closed state from below 10% to 100% of the minimum pulse length.

[0168] The third drive pulse lengths increase from at least 9% to 100% of the minimum pulse length. In other words, for each period of the second alternating signal C3, the switching element 35 is in a closed state from starting form at least 9% to 100% of the minimum pulse length.

[0169] A DC pulse detection means detects the minimum of the DC pulses and hence a DC pulse duration.

[0170] The activation start time T2a is a switch-on time start time for the third duty cycles which is determined based on the end of the previous DC pulse and the difference of the DC pulse duration and the third subsequence duration D3 as switch-on time or activation time.

[0171] A sequence duration detection means detects a sequence duration as a number of sequence DC pulses by stepwise increasing a number of DC pulses until the variation of the heating power during a sequence is in the predetermined range.

[0172] A sequence duration setting means sets a sequence duration such that the variation and/or reduction of the heating power is in the predetermined range.

[0173] For example, if the variation and/or reduction of the heating power shall be in a predetermined range between 3% and 30%, a sequence duration of 5, 8 or 10 DC pulses may be required. This can also be evaluated stepwise, by stepwise increasing the number of DC pulses.

[0174] The number of DC pulses in a sequence determines the sequence duration, wherein the number of DC pulses in the first subsequence determines the first subsequence duration, wherein the number of DC pulses in the second subsequence determines the second subsequence duration.

[0175] The first subsequence duration and the second subsequence duration are determined such that a required power is obtained as heating power.

[0176] The number of DC pulses in the first subsequence and the number of DC pulses in the second subsequence are determined such that a required power is obtained.

[0177] The number of DC pulses in the first subsequence is obtained by multiplying the number of DC pulses in the sequence with the quotient of the requested power and the minimum continuous power with, and, in particular, rounding up or down the result.

[0178] The heating unit 2 comprises a power driving control unit 51 for determining the ratio between the first and the second duration and/or for determining the first and the second duration determined based on a requested power level.

[0179] In at least one operating mode, the predetermined power PM is the minimum continuous power and the requested power PR is lower than the predetermined power PM. In particular, PM is the minimum continuous power.

[0180] The switching element 35 is a quasi-resonant switching element.

[0181] The resonant tank 30 comprises a capacitive element 31 and an inductive element 32.

[0182] The resonant tank 30 with a capacity 31 as C as well as an inductance 32 as L corresponds with or has a resonance frequency F1, which is at least essentially

$$F1= 1/(2*pi*sqrt(L*C)).$$

[0183] Hence, for an excitation signal, the period P1 must be at least essentially

$$P1 = 2*pi*sqrt(L*C)$$

and correspondingly, the length L3 of a pulse must be at least approximately or in the range of

$$L3 = pi*sqrt(L*C),$$

if the resonant tank 30 shall be excitated. The resonant tank 30 is switched off, if the pulse length is much smaller than the resonance pulse length, in particular if it is smaller than 1/100 of the resonance pulse length.

[0184] The induction heating device 1 comprises at least one, two, at least two, four, at least four, six or at least six induction heating units 2.

[0185] The induction heating device 1 further comprises a rectifying means 10 for rectifying an external AC power supply signal into a pulsed bus DC supply signal comprising a series of DC pulses for supplying at least one, two, at least two, four, at least four, six or at least six induction heating units 2.

[0186] The induction heating device 1 comprises a power level defining unit 60, in particular a user interface, for determining at least one requested power level of the induction heating device 1.

[0187] Further, the induction heating device 1 comprises at least one detecting unit for detecting starting times of the DC pulses.

[0188] FIG. 2 and 3 show an induction cooking appliance 1, in particular domestic induction cooking appliance and/or induction hob, comprising one, at least one, two, at least two, four, at least four, six or at least six oscillation circuits.

[0189] The induction cooking appliance 1 comprises a user interface 60 for requesting a power for the quasi-resonant oscillation circuit.

[0190] The induction cooking appliance 1 comprises a voltage supply unit 10 for supplying voltage to the power supply connector of the oscillation circuits.

[0191] In an embodiment, the induction hob 1 comprises four oscillation circuits, which each comprise an inductor, as well as a user interface 60 for requesting power from each of the inductors.

[0192] A domestic induction cooking appliance is in particular an induction cooking appliance which is specifically designed for use in household and/or at home. Such devices have considerably different requirements compared to professional cooking appliances, for example cost and/or usability and/or space requirements. A domestic induction cooking appliance is in particular not an induction cooking appliance which is specifically designed for professional use, for example in canteen kitchens, restaurants or in general for commercial cooking.

[0193] The voltage supply unit 10 comprises a bridge rectifier and/or a bus capacitor 11.

[0194] The voltage supply unit 10 is in particular, more in particular only, supplied with power by a one-phase power supply, which in particular means that the voltage supply unit 10 is supplied with power by a phase connector and neutral connector, which in particular supply power from an AC power supply with a frequency of about 50 to 60 Hz and a voltage of about 100 to 240 V.

[0195] As an example, FIG 3 shows four oscillation units 2 according to the invention, wherein a first power supply 10 supplies power from a first voltage phase to two oscillation units 2 by means of a first DC bus. A second power supply 10 supplies power from a second voltage phase to two oscillation units 2 by means of a second DC bus.

[0196] In a more general approach, a first power supply 10 supplies power from a first voltage phase to at least two oscillation units 2, for example by means of a first DC bus. A second power supply 10 supplies power from a second voltage phase to at least two oscillation units 2, for example by means of a second DC bus.

[0197] The resonant tank 30, in particular quasi-resonant resonant tank 2, which can also be called an induction generator, produces power based on a working routine with the two phases Ton as ON time and Toff as OFF time.

[0198] During the Ton phase, the switching element 35 is closed and current flows through it, accumulating power in the inductor 32. The voltage VCE across the switching element 35 is short-circuited to ground 22 so its value is 0.

[0199] During the Toff phase, instead, the switching element 35 is open so that current and voltage resonate in the resonant tank 30.

[0200] In the embodiment, the switching element 35 is or at least can be an IGBT (insulated gate bipolar transistor), and preferably the transistor 36 and the diode 37 are operated in parallel.

List of reference numerals

[0201]

1	Induction hob
2	Oscillation circuit
10	Power supply circuit
11	DC bus capacitor
21	First node
22	Second node
23	Third node
30	Resonant tank
31	Capacitive resonant element
32, 33	Inductive resonant element
35	Switching element
36	Transistor
37	Diode
38	Driving signal
40	Measuring unit
50	Control unit
51	Power driving control unit
52	Driving unit
60	Power level defining unit
C1 to C3	First to third duty cycle
D1 to D3	First to third duration
P1 to P5	First to fifth DC pulse

S1 to S3	First to third subsequence
T1 to T6	First to sixth starting time of DC pulse
PH	Heating power
PM	Predetermined power
PR	Requested power
VCE	Resonator voltage
VBUS	DC supply voltage
VGND	Ground voltage
VMAIN	AC voltage supply

Claims

1. Induction heating unit (1) for a cooking device, in particular for an induction cooking device, more particularly for an induction hob, comprising

- at least one resonant tank (30) with at least one induction heating element (32),
- a power requesting unit (60) for requesting a power (PR) of the at least one induction heating element (32),
- a driving unit (52) for driving the resonant tank (30), in particular by oscillating the resonant tank (30) by means of a switching element (35), by a driving signal (38) comprising a series of subsequent sequences for generating a heating power (PH), each sequence comprising

  ◦ a first subsequence (S1) with a first alternating signal and with a first subsequence duration (D1), causing an activation of the resonant tank (30) with a predetermined power (PM),
  ◦ a subsequent second subsequence (S2) with an at least essentially non-alternating signal and with a second subsequence duration (D2), causing a deactivation of the resonant tank (30) and
  ◦ a subsequent third subsequence (S3) with a second alternating signal and with a third subsequence duration (D3), causing an activation of the resonant tank (30) with less than the predetermined power (PM).

2. Induction heating unit according to claim 1,

- wherein the driving signal (38) toggles or is configured to toggle, in particular in at least one or in each subsequence, between at least one first driving state, in particular resulting in an at least essentially closed state of the switching element (35), and at least one second driving state, in particular resulting in an at least essentially opened state of the switching element (35),
- wherein in particular the first driving state is determined by a first driving signal parameter, preferably by a first driving signal voltage or by a first driving signal current, and the second driving state is determined by a second driving signal parameter, preferably by a second driving signal voltage or by a second driving signal current,
- wherein in particular the first driving state and/or the second driving state vary between the first, the second and/or the third subsequence,
- wherein in particular the first driving signal parameter and/or the second driving signal parameter of the third subsequence vary compared to the first driving signal parameters and/or the second driving signal parameters of the first subsequence and/or the second subsequence,
- wherein in particular the first driving signal voltage and/or the second driving signal voltage of the third subsequence is/are lower or higher than the first driving signal voltage and/or the second driving signal voltage of the first subsequence and/or the second subsequence,
- wherein in particular the first driving signal voltage and/or the second driving signal voltage are gate voltages of the switching element (35),
- wherein in particular the switching element (35) is or comprises a transistor, more in particular an insulated gate bipolar transistor, IGBT.

3. Induction heating unit according to claim 1 or 2, wherein the heating power (PH) is generated corresponding to the requested power (PR).

4. Induction heating unit according to claim 1, 2 or 3, wherein, in at least one operating mode, a first subsequence duration (D1) and a second subsequence duration (D2) are selected such that a variation and/or reduction of the heating power (PH) is in a predetermined range, in particular such that the variation and/or reduction of the power (PH) in relation to the requested power (PR) is more than a predetermined minimum variation and/or reduction and less than a predetermined maximum variation and/or reduction, wherein more in particular the minimum variation and/or reduction is 3%, in particular 5% and/or wherein the maximum variation and/or reduction is 30%, in particular 20%, more in particular 10%.

5. Induction heating unit according to any one of the preceding claims,
wherein the first subsequence (S1) with first alternating signals starts at a first starting time (T1) of a first DC pulse (P1) and ends at a second starting time (T2) of an, in particular subsequent, second DC pulse (P2), with a first subsequence duration (D1), a first drive frequency, a first duty cycle (C1) and/or a first Ton time, wherein in particular the first subsequence duration (D1) is determined by and/or at least essentially equal to the duration of the first DC pulse

(P1) or determined by and/or at least essentially equal to the added duration of multiple DC pulses.

6. Induction heating unit according to any one of the preceding claims,
wherein the second subsequence (S2) with non-alternating signals starts at the second starting time (T2) of the/a second DC pulse (P2) and ends at an activation start time (T2a), at a third subsequence duration (D3) before a third starting time (T3) of a third DC pulse (P3), in particular at a third subsequence duration (D3) between the second starting time (T2) of a second DC pulse (P2) and the third starting time (T3) of the DC third pulse (P3), with a second subsequence duration (D2), a second drive frequency of at least essentially zero, a second duty cycle of at least essentially zero (C2) and/or a second Ton time of at least essentially zero, wherein in particular the second subsequence duration (D2) is determined by the duration of the second DC pulse (P2) or equal to the added duration of multiple DC pulses, minus the third subsequence duration (D3).

7. Induction heating unit according to any one of the preceding claims,
wherein the third subsequence (S3) with second alternating signals starts at an activation start time (T2a), a third subsequence duration (D3) before the third starting time (T3) of a third DC pulse (P3), between a second starting time (T2) of a second DC pulse (P2) and a third starting time (T3) of the DC third pulse (P3), and ends at the starting time (T3) of the third DC pulse (P3), with a third drive frequency as well as duty cycles and/or a Ton time increasing from a third duty cycle or third Ton time to the first duty cycle (C1) or first Ton time, wherein in particular the third subsequence duration (D3) is less than 30%, in particular less than 20%, more in particular equal to 10% or less than 10% of the DC pulse duration,

- wherein in particular the or a first driving signal voltage and/or the or a second driving signal voltage of the third subsequence is/are lower or higher than the or a first driving signal voltage and/or the or a second driving signal voltage of the first subsequence and/or the second subsequence,
- wherein in particular the first driving signal voltage and/or the second driving signal voltage are gate voltages of the switching element (35),
- wherein in particular the switching element (35) is or comprises a transistor, more in particular an insulated gate bipolar transistor, IGBT.

8. Induction heating unit according to any one of the preceding claims,
wherein the first alternating signal (C1) is a pulse wave and/or comprises a, in particular constant, first drive pulse length, in particular Ton time and/or Toff time and/or a first duty cycle and/or first frequency, wherein the first alternating signal generates the predetermined power (PM).

9. Induction heating unit according to any one of the preceding claims,
wherein the at least essentially non-alternating signal (C2) with a second pulse length, a second duty cycle and a second frequency at least essentially deactivates or shuts off the resonant tank, in particular wherein the non-alternating signal (C2) is a constant signal, which is more in particular constantly zero.

10. Induction heating unit according to any one of the preceding claims,
wherein the second alternating signal (C3) comprises increasing third drive pulse lengths, in particular increasing third Ton times, increasing third duty cycles and/or an, in particular at least essentially constant, third drive frequency and/or generates a heating power starting from less than to at least essentially equal to the minimum continuous power in the resonant tank (30) and/or to the predefined and/or requested power,

- wherein in particular the/a first driving signal voltage and/or the/a second driving signal voltage of the third subsequence is/are lower or higher than the first driving signal voltage and/or the second driving signal voltage of the first subsequence and/or the second subsequence,
- wherein in particular the first driving signal voltage and/or the second driving signal voltage are gate voltages of the switching element (35),
- wherein in particular the switching element (35) is or comprises a transistor, more in particular an insulated gate bipolar transistor, IGBT.

11. Induction heating unit according to any one of the preceding claims,
wherein a sequence duration detection means detects a sequence duration as a number of sequence DC pulses by stepwise increasing a number of DC pulses until the variation of the heating power during a sequence is in a predetermined range and/or
wherein a sequence duration setting means sets a sequence duration such that the variation of the heating power is in the/a predetermined range.

12. Induction heating unit according to any one of the preceding claims,
wherein the number of DC pulses in a sequence determines the sequence duration, wherein the number of DC pulses in the first subsequence determines the first subsequence duration, wherein the

number of DC pulses in the second subsequence determines the second subsequence duration, and/or
wherein the first subsequence duration and the second subsequence duration are determined such that a required power is obtained as heating power, and/or
wherein the number of DC pulses in the first subsequence and the number of DC pulses in the second subsequence are determined such that a required power is obtained, and/or wherein the number of DC pulses in the first subsequence is obtained by multiplying the number of DC pulses in the sequence with the quotient of the requested power and the minimum continuous power and, in particular, rounding up or down the result.

13. Induction heating unit according to any one of the preceding claims, with

- a power driving control unit (51) for determining the ratio between the first subsequence duration and the second subsequence duration and/or for determining the first subsequence duration and the second subsequence duration based on a requested power level, and/or
- wherein in particular the predetermined power (PM) is the minimum continuous power and/or wherein the requested power (PR) is lower than the predetermined power, and/or
- the switching element (35) being a quasi-resonant switching element and/or
- the resonant tank (30) comprising a capacitive and an inductive element.

14. Induction cooking device (1) with at least one induction heating unit according to any one of the preceding claims, comprising

- at least one, two, at least two, four, at least four, six or at least six induction heating units according to one of the preceding claims, further comprising in particular
    - a rectifying means for rectifying an external AC power supply signal into a pulsed bus DC supply signal comprising a series of DC pulses for supplying the at least one, two, at least two, four, at least four, six or at least six induction heating units and/or
- a power level defining unit (60), in particular a user interface, for determining at least one requested power level of the induction heating device (1) and/or
- at least one detecting unit for detecting starting times of the DC pulses.

15. Method for operating an induction heating unit (1), in particular according to any one of the preceding claims 1 to 13, the method comprising

- by a power requesting unit (60), requesting a power (PR) of the at least one induction heating element (32),
- by a driving unit (52), driving the resonant tank (30), in particular oscillating the resonant tank (30) by means of a switching element (35), by a driving signal comprising a series of subsequent sequences for generating a heating power (PH), each sequence comprising
    - ◦ a first subsequence (S1) with a first alternating signal and with a first subsequence duration (D1), causing an activation of the resonant tank (30) with a predetermined power (PM),
    - ◦ a subsequent second subsequence (S2) with an at least essentially non-alternating signal and with a second subsequence duration (D2), causing a deactivation of the resonant tank (30) and
    - ◦ a subsequent third subsequence (S3) with a second alternating signal, causing an activation of the resonant tank (30) with less than the predetermined power (PM).

16. Method for operating an induction heating unit (1) according to claim 15, the method further comprising

- by a power driving control unit (51), determining the ratio between the first subsequence duration and the second subsequence duration and/or determining the first subsequence duration and the second duration determined based on a requested power level (PR), wherein in particular the predetermined power (PM) is the minimum continuous power and the requested power (PR) is lower than the predetermined power (PM).

FIG 1

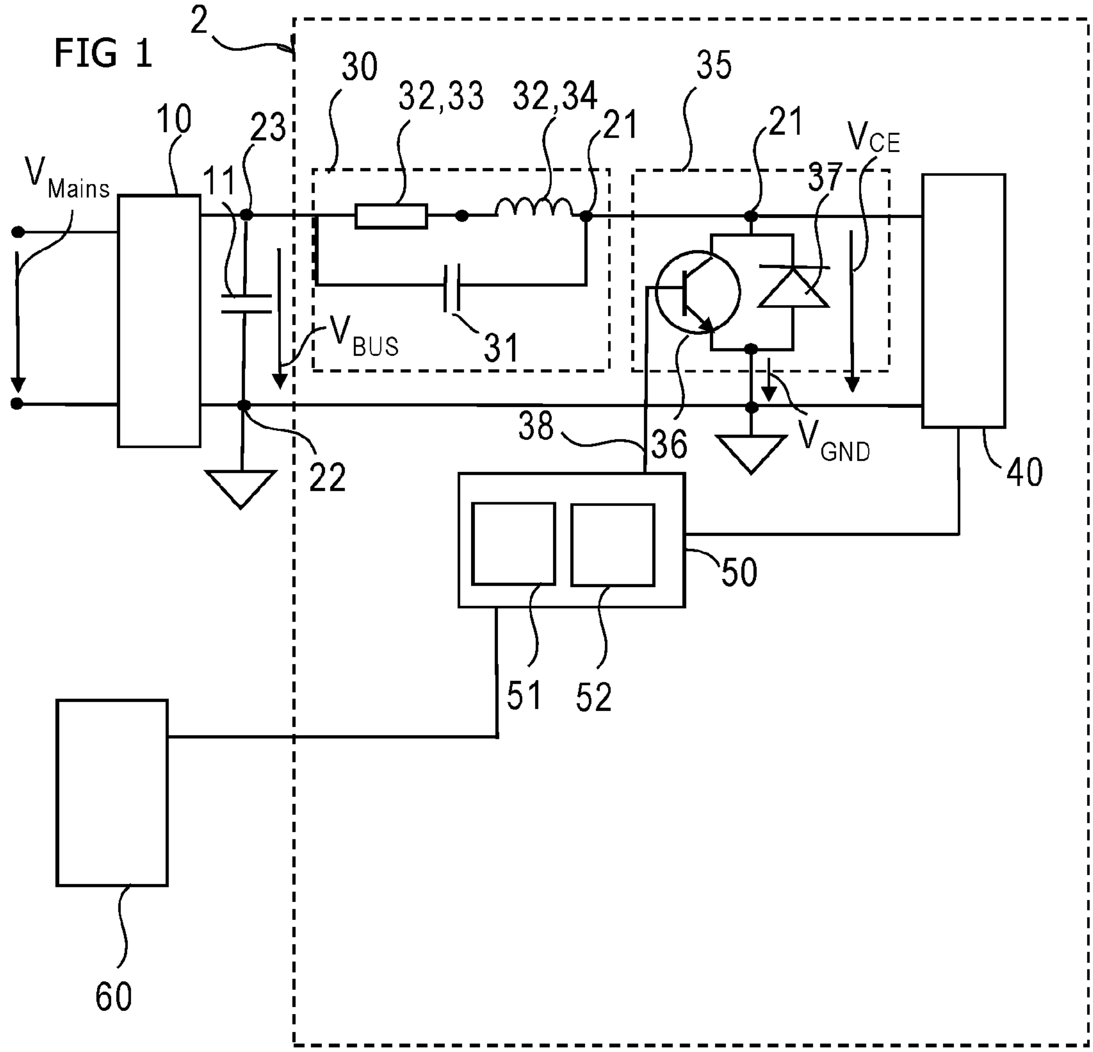

2
30
32,33
32,34
21
35
21
V_{CE}
10
23
V_{Mains}
11
37
V_{BUS}
31
38
36
V_{GND}
22
40
50
51
52
60

FIG 2

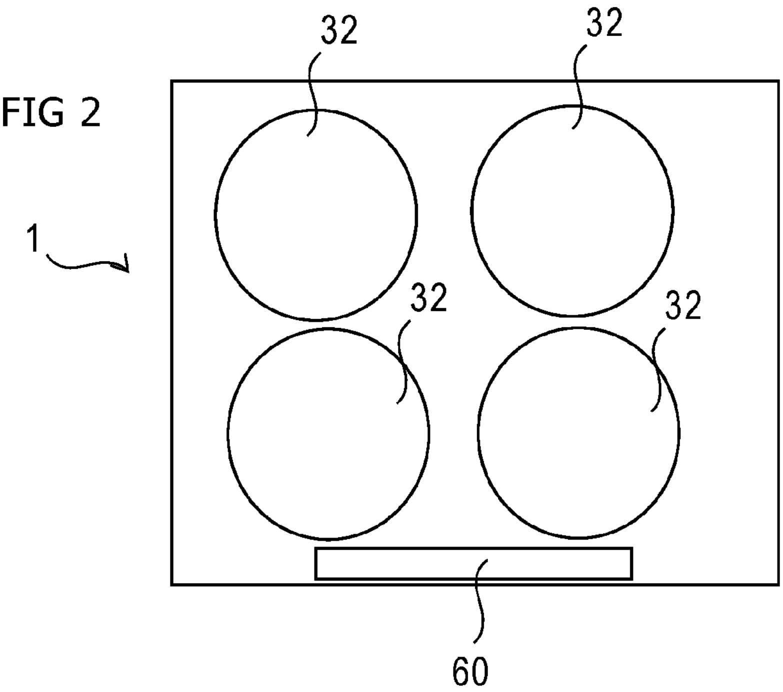

32
32
1
32
32
60

FIG 3

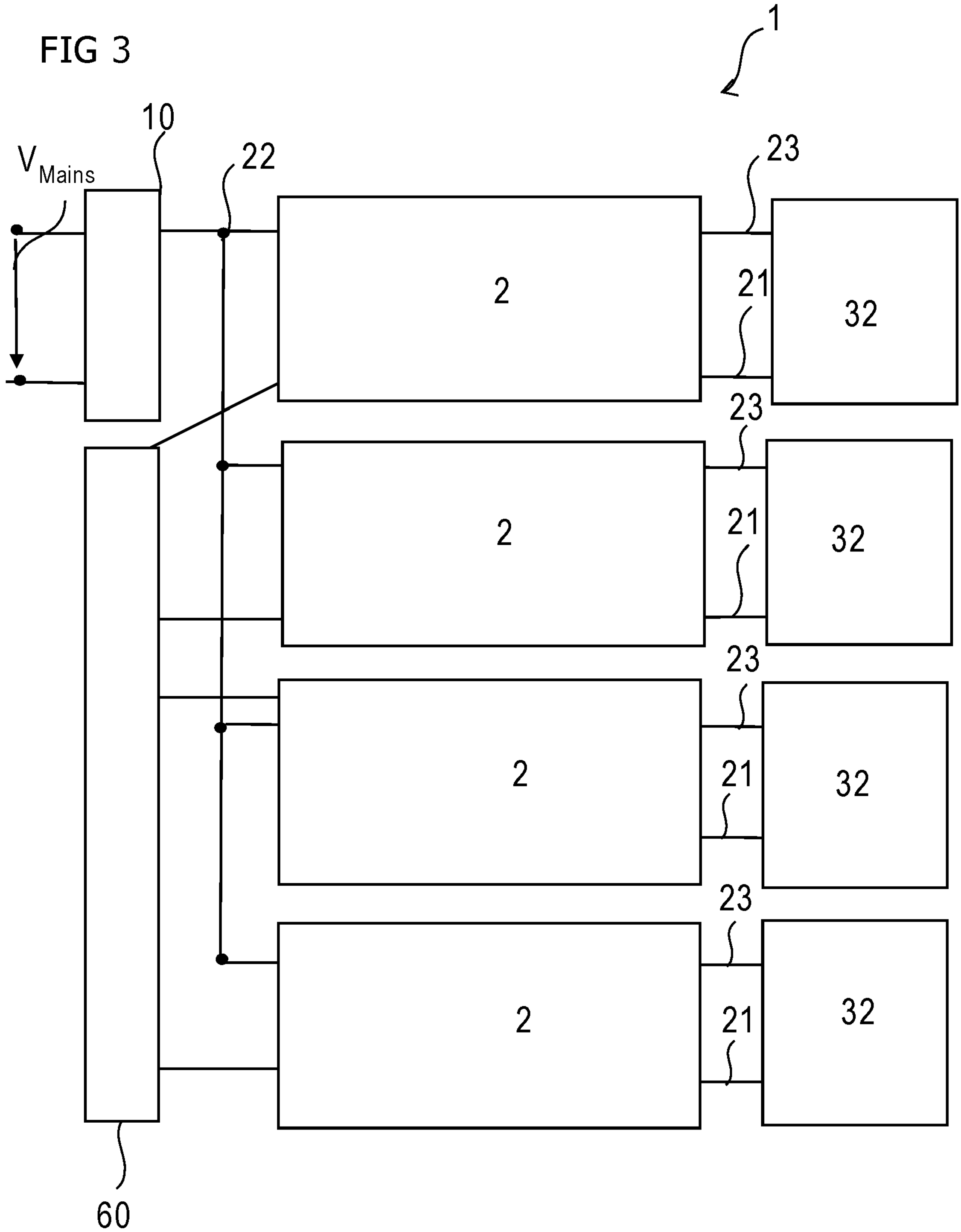


FIG 4

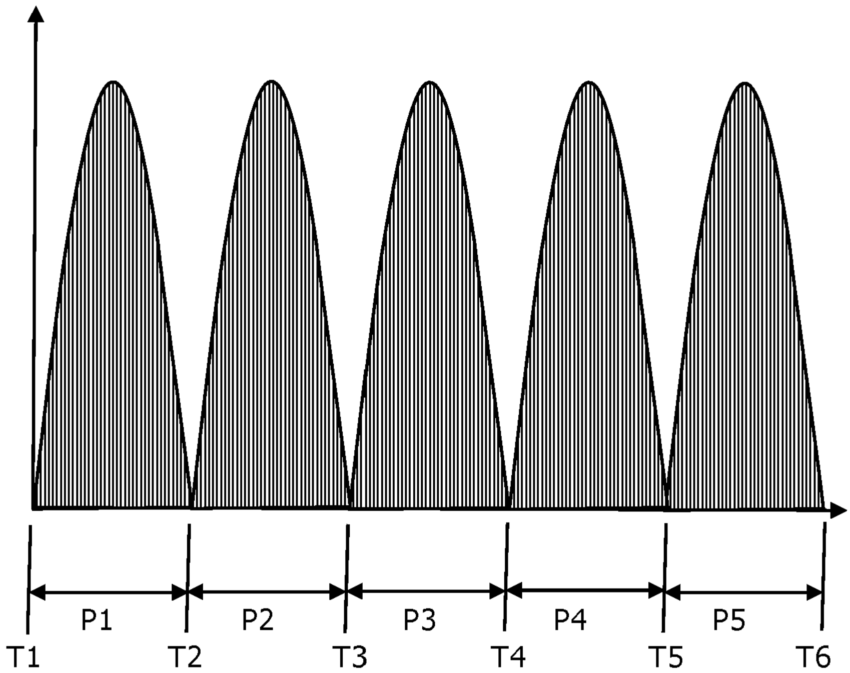
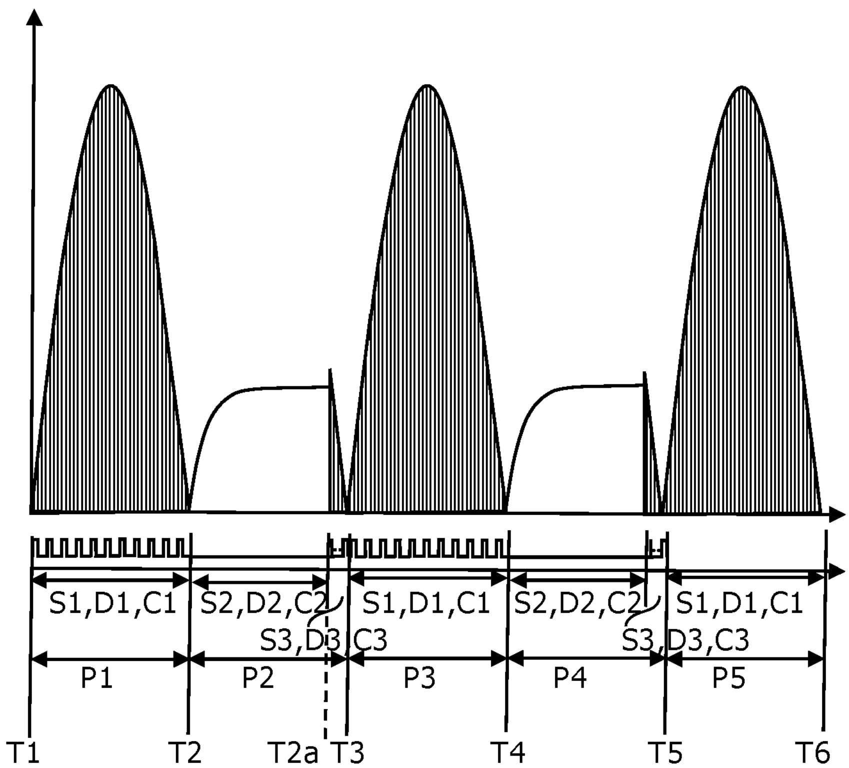

P1
P2
P3
P4
P5
T1
T2
T3
T4
T5
T6

FIG 5


S1,D1,C1
S2,D2,C2
S1,D1,C1
S2,D2,C2
S1,D1,C1
S3,D3,C3
S3,D3,C3
P1
P2
P3
P4
P5
T1
T2
T2a
T3
T4
T5
T6

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EUROPEAN SEARCH REPORT

Application Number
EP 20 20 7654

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Place of search	Date of completion of the search	Examiner
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