(19) Octrooicentrum Nederland

(11) 2034132

(12) B1 OCTROOI

(21) Aanvraagnummer: **2034132**

(22) Aanvraag ingediend: **13 februari 2023**

(62)

(51) Int. Cl.:
H02M 1/00 (2023.01) **H02M 5/10** (2023.01) **H02M 3/335** (2023.01)

(30) Voorrang:
-

(41) Aanvraag ingeschreven:
3 september 2024

(43) Aanvraag gepubliceerd:
-

(47) Octrooi verleend:
3 september 2024

(45) Octrooischrift uitgegeven:
16 september 2024

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(54) **A switching power electronic converter arranged to determine a measure for a DC-bias current flowing through an electromagnetic component, as well as a corresponding method.**

(57) A switching power electronic converter arranged to determine a measure for a DC-bias current flowing through an electromagnetic component, the switching power electronic converter comprising a Direct Current, DC, link stage to provide a DC voltage, a switching stage comprising active switching elements, operated at a switching frequency, for converting the DC voltage to a series of voltage pulses provided to the electromagnetic component, and the electromagnetic component connected, directly or indirectly, to a switching node of the switching stage, wherein the switching power electronic converter further comprises a DC-bias current detection stage, provided at the DC link stage, wherein the DC-bias current measuring stage is arranged to determine the measure for the DC-bias current by determining a current, or voltage, in the DC link stage having a frequency component at the switching frequency.

NL B1 2034132

Dit octrooi is verleend ongeacht het bijgevoegde resultaat van het onderzoek naar de stand van de techniek en schriftelijke opinie. Het octrooischrift komt overeen met de oorspronkelijk ingediende stukken.

Title

A switching power electronic converter arranged to determine a measure for a DC-bias current flowing through an electromagnetic component, as well as a corresponding method.

Technical field

The present disclosure is related to switching power electronic converters, for example switched mode power supplies, wherein such converters are provided with functionality to determine a measure for a DC-bias current flowing through an electromagnetic component.

Background

A Direct Current, DC, bias current flowing in a primary side of a transformer of a galvanic isolated switched mode power supply is a common challenge that engineers are facing. Typically, it is induced by a DC current flowing through one or more windings of the transformer, resulting in a bias of the magnetic flux in the transformer core. This bias may be problematic as it can increase the core losses of the transformer and may drive the transformer core into saturation, which deteriorates the operation of and can even result in malfunctioning of the converter.

The present disclosure is directed to a switching power electronic converter as well as a corresponding method to at least provide for a measure for the DC-bias in the magnetic flux of the transformer in transformer-isolated converters.

Such DC bias currents are traditionally countered using active control through measurement of either the magnetic flux in the transformer core or high accuracy measurements of the current through the transformer windings, or even by placing capacitors in series with the transformer windings to passively block any steady-state DC current from flowing into the transformer. This is undesired as it requires the addition of either expensive or physically large components, making the total system larger and more expensive.

Summary

It is an object of the present disclosure to provide for a switching power electronic converter that is able to provide for a measure for the above identified DC bias current. It is a further object to provide for a corresponding method.

In a first aspect of the present disclosure, there is provided a switching power electronic converter arranged to determine a measure for a DC-bias current flowing through an electromagnetic component, the switching power electronic converter comprising:

- a Direct Current, DC, link stage to provide a DC voltage,
- a switching stage comprising active switching elements, operated at a switching frequency, for converting the DC voltage to a series of voltage pulses provided to the electromagnetic component;
- the electromagnetic component connected, directly or indirectly, to a switching node of the switching stage,

wherein the switching power electronic converter further comprises:

- a DC-bias current detection stage, provided at the DC link stage, wherein the DC-bias current measuring stage is arranged to determine the measure for the DC-bias current by determining a current, or voltage, in the DC link stage having a frequency component at the switching frequency.

The inventors have found that a measure for the DC-bias current may be determined at the DC link stage of the corresponding converter. The DC-bias current, therefore, does not need to be measured at the electromagnetic component itself. In prior art solutions, the DC-bias current is determined by either measuring the voltage over, or the current flowing through, the electromagnetic component.

The inventors have found a beneficial method for determining the measure for the DC-bias current: The fact that the DC-bias current flowing through the electromagnetic component, for example a transformer, is transformed by the power electronic converter into a DC-link current having a harmonic component with a frequency that is equal to the switching frequency of the converter.

The DC-bias current flowing through the electromagnetic component will thus be transformed, and will be visible as a current having a harmonic component equal to the switching frequency of the active elements in the switching stage.

Several implementation examples for the detection of the DC-bias current, based on the detection of this harmonic component of the DC-link current or voltage are disclosed, which may be readily implemented and may be very effective at the same time. Using the proposed examples, there is no need for very high-accuracy current or flux sensors, and the DC bias can be detected by means of current or voltage sensors.

The present disclosure describes a so-called switching power electronic converter. A switched mode power supply, SMPS, is – for example - a specific type of power electronic converter that is designed to convert electrical power from one form to another, typically AC to DC or vice versa. SMPSs are widely used in various applications because of their high efficiency, low weight and small size compared to linear power supplies.

Power electronic converters refer to a general category of devices that convert electrical power from one form to another. It includes switched mode power supplies or switching power electronic converters. Typical examples include DC-DC converters, AC-AC converters, and DC-AC converters.

The electromagnetic component is, typically, a transformer or an inductor.

In a switched mode power supply, SMPS, a transformer or inductor may be used. Typically, a transformer is used to transfer energy through its magnetic field, while an inductor serves the purpose of storing energy within its magnetic field.

Transformers may be utilized to change the voltage level and to provide electrical isolation and protection. Inductors, on the other hand, may be employed to shape current waveforms and to smooth voltage ripple

The primary function of the inductor is as an intermediate energy storage element, where energy is alternately stored and released during the switching period. A transformer can have a similar role, but is primarily used for galvanic isolation between the input and output ports, which may be beneficial to protect sensitive loads and improve safety aspects.

The DC-link stage in an electronic converter is a component that is used to provide a stable intermediate DC voltage from which the output voltage is derived. It may consist of a (large) input capacitor that is connected in parallel with the (input

of the) switching stage, which is typically built up out of power switches such as MOSFETs or IGBTs.

The DC-link stage may thus maintain a stable intermediate DC voltage and may ensure a reliable operation of an electronic converter.

In accordance with the present disclosure, the DC-bias current detection stage is provided at the DC link stage, This means that the DC-bias current detection stage may located before the switching stage – i.e. at the opposite side of the switching stage compared to the electromagnetic component.

The DC-bias current detection stage may focus on measuring a current flowing at the DC-link stage that has a harmonic component with the frequency that is equal to the switching frequency of the switching stage. That specific current may form a measure for the DC-bias current. That specific current may, for example, result in a voltage that can be measured, wherein the voltage may then form the measure for the DC-bias current.

The present disclosure is directed to provide for a measure for the DC-bias current. It is not necessarily required to provide for an actual quantity of the DC-bias current. The measure that is obtained may be directly proportional to the DC-bias current, without necessarily knowing the actual quantity of the DC-bias current.

The switching stage in a switched-mode power supply, SMPS, may be the stage where the voltage and current are rapidly turned on and off, allowing the power supply to control the amount of energy delivered to a load. The switching stage is typically performed by a switch, such as a metal-oxide-semiconductor field-effect transistor, MOSFET, that operates at a certain frequency.

The switching stage may be of importance for a switched-mode power supply as it enables the power supply to regulate the output voltage or current by controlling the on-time of the switch. The switching frequency is typically in the kilohertz or megahertz range, and it is typically chosen such that it is high enough to allow efficient control of the output power, yet low enough to minimize the size and cost of the filter components.

The output voltage or current from the switching stage may then be transformed by an output stage, which typically includes a transformer or inductor to provide a stable, regulated output voltage or current to the load. The switching stage, combined with the output stage, allows a switched-mode power supply to provide high

efficiency, fast response, and high power density compared to traditional linear power supplies.

In an example, the DC-bias current detection stage comprises a series current sensor for determining the current in the DC link stage flowing to the switching stage.

A specific implementation may encompass one or more resistors, for example placed in parallel, wherein a voltage over those resistors is a measure for the current flowing through the switching stage.

It is noted that a fluxgate sensor, current transformer or a hall-effect sensor could also be used for this particular purpose.

For high power converters, a current transformer may be used. A resistor-based current sensor may ale be used, in series with the electromagnetic component to measure the DC-bias current.

In a further example, the DC link stage comprises an input capacitor, and wherein the DC-bias current detection stage is provided in parallel to the input capacitor.

The inventors have found that it may be beneficial to measure the voltage fluctuations over the input capacitor, as those fluctuations may form a measure for the DC-bias current. The benefit of this particular example is that less energy is consumed compared to the series current sensor example, and less additional components are necessary for implementation.

The DC-bias current detection stage may, for example, comprise a filter that is associated with the switching frequency. As mentioned above, the DC-bias current flowing through the electromagnetic component may be transformed to a current having a harmonic component of the switching frequency. The filter may be associated, related, or even tuned to the switching frequency, as the current having that particular frequency is of interest.

The filter may be a band-pass filter that is specifically tuned, for example, to the switching frequency. The filter may also encompass any other type of filter, for example a high-pass filter.

The filter may be a digital filter or an analogue filter.

It is further noted that the converter may comprise a controller which performs at least a part of the functionality described in this disclosure. The controller

may, for example, be a micro-controller, Field Programmable Gate Array, FPGA, an Application Specific Integrated Controller, ASIC, or anything alike.

In a further example, the switching power electronic converter comprises:

- a DC-bias control circuit arranged for controlling the active switching elements based on the measure for the DC-bias current.

The inventors have found that the determined measure for the DC-bias current may be used, for example by a controller, to actually control the active switching stage. For example, FET's present in the active switching stage may be controlled based on the determined DC-bias current. This may mitigate, or reduce, the DC-bias current.

The DC-bias control circuit as defined above may be implemented digitally.

In another example, the DC-bias control circuit comprises an Analog to Digital Converter, ADC, wherein the ADC is arranged to sample at least at twice the switching frequency. More specifically, samples at twice the switching frequency may be used.

The inventors have found that it may be beneficial to sample at twice the switching frequency as all even-harmonics of the switching frequency are attenuated even further.

In a further example, the electromagnetic component is any of:

- an inductor;
- a winding of a transformer;
- a motor winding;
- an actuator winding;
- a generator winding;
- a circuit inductance.

In a second aspect of the present disclosure, there is provided a method of operating a switching power electronic converter in accordance with any of the previous claims, wherein the method comprises the steps of:

- determining, by the DC-bias current detection stage, the measure for the DC-bias current by determining a current, or voltage, in the DC link stage having a frequency component at the switching frequency.

It is noted that the advantages as explained with reference to the first aspect of the present disclosure, being the switching power electronic converter, are also applicable to the second aspect of the present disclosure, being the method of operating such a switching power electronic converter.

In an example, the DC-bias current detection stage comprises a series current sensor, and wherein the method comprises the step of:

- determining, by the series current sensor, the current in the DC link stage flowing to the switching stage.

In a further example, the DC link stage comprises an input capacitor, and wherein the DC-bias current detection stage is provided in parallel to the input capacitor.

In yet another example, the DC-bias current detection stage comprises a filter associated with the switching frequency, for example a band-pass filter or a high-pass filter.

In a further example, the switching power electronic converter comprises a DC-bias control circuit, wherein the method comprises the step of:

- controlling, by the DC-bias control circuit, the active switching elements based on the measure for the DC-bias current.

In yet another example, the DC-bias control circuit comprises an Analog to Digital Converter, ADC, wherein the method comprises the step of:

- sampling, by the ADC, at, at least, twice the switching frequency

The DC-bias control circuit may thus use samples at twice the switching frequency.

The present disclosure is described in conjunction with the appended figures. It is emphasized that, in accordance with the standard practice in the industry, various features are not drawn to scale. In fact, the dimensions of the various features may be arbitrarily increased or reduced for clarity of discussion.

In the appended figures, similar components and/or features may have the same reference label. Further, various components of the same type may be distinguished by following the reference label by a dash and a second label that distinguishes among the similar components. If only the first reference label is used in the specification, the description is applicable to any one of the similar components having the same first reference label irrespective of the second reference label.

The above and other aspects of the disclosure will be apparent from and elucidated with reference to the examples described hereinafter.

Brief description of the drawings

Fig. 1 discloses a single-phase DC/AC converter in accordance with the prior art.

Fig. 2 discloses different examples of a switching power electronic converter in accordance with the present disclosure.

Fig. 3 discloses a simplified model of the converter in the switching frequency domain.

Fig. 4 discloses a bode diagram of the transfer function of the switching-frequency harmonic current to the filter inductor voltage.

Fig. 5 discloses a transformer-connected full-bridge and a corresponding AC terminal voltage.

Fig. 6 discloses simulated waveforms of the bridge AC voltage and filter inductor voltage.

Fig. 7 discloses a control loop in accordance with the present disclosure.

Fig. 8 discloses a transformer-connected three-phase DC/AC converter.

Detailed description

It is noted that in the description of the figures, same reference numerals refer to the same or similar components performing a same or essentially similar function.

A more detailed description is made with reference to particular examples, some of which are illustrated in the appended drawings, such that the manner in which the features of the present disclosure may be understood in more detail. It is noted that the drawings only illustrate typical examples and are therefore not to be considered to limit the scope of the subject matter of the claims. The drawings are incorporated for facilitating an understanding of the disclosure and are thus not necessarily drawn to scale. Advantages of the subject matter as claimed will become

apparent to those skilled in the art upon reading the description in conjunction with the accompanying drawings.

The ensuing description above provides preferred exemplary embodiment(s) only, and is not intended to limit the scope, applicability or configuration of the disclosure. Rather, the ensuing description of the preferred exemplary embodiment(s) will provide those skilled in the art with an enabling description for implementing a preferred exemplary embodiment of the disclosure, it being understood that various changes may be made in the function and arrangement of elements, including combinations of features from different embodiments, without departing from the scope of the disclosure.

Unless the context clearly requires otherwise, throughout the description and the claims, the words "comprise," "comprising," and the like are to be construed in an inclusive sense, as opposed to an exclusive or exhaustive sense; that is to say, in the sense of "including, but not limited to." As used herein, the terms "connected," "coupled," or any variant thereof means any connection or coupling, either direct or indirect, between two or more elements; the coupling or connection between the elements can be physical, logical, electromagnetic, or a combination thereof. Additionally, the words "herein," "above," "below," and words of similar import, when used in this application, refer to this application as a whole and not to any particular portions of this application. Where the context permits, words in the Detailed Description using the singular or plural number may also include the plural or singular number respectively. The word "or," in reference to a list of two or more items, covers all of the following interpretations of the word: any of the items in the list, all of the items in the list, and any combination of the items in the list.

These and other changes can be made to the technology in light of the following detailed description. While the description describes certain examples of the technology, and describes the best mode contemplated, no matter how detailed the description appears, the technology can be practiced in many ways. Details of the system may vary considerably in its specific implementation, while still being encompassed by the technology disclosed herein. As noted above, particular terminology used when describing certain features or aspects of the technology should not be taken to imply that the terminology is being redefined herein to be restricted to any specific characteristics, features, or aspects of the technology with which that

terminology is associated. In general, the terms used in the following claims should not be construed to limit the technology to the specific examples disclosed in the specification, unless the Detailed Description section explicitly defines such terms. Accordingly, the actual scope of the technology encompasses not only the disclosed examples, but also all equivalent ways of practicing or implementing the technology under the claims.

Figure 1 shows a block diagram of a transformer-connected single-phase DC/AC converter, which is often a building block of a large variety of isolated power electronics converters.

For example, a dual active bridge converter can be derived by adding an active bridge and a DC-link to the secondary side of the transformer. Volt-second imbalances are likely to be applied on both sides of the transformer. To prevent DC-biasing of the flux density in the transformer core, volt-second balancing of both the primary and secondary terminals of the transformer is demanded. For simplicity but without loss of generality, it is assumed that the voltage of the secondary side is free of a DC component, and it can be modelled as a voltage source.

If the voltage waveform that the primary bridge applies to the transformer winding has a DC component, a DC-bias current will flow through the transformer in steady state operation. This DC component will be modulated by the bridge and appear in the DC-link current as a component with the switching frequency as fundamental frequency, in addition to the higher harmonic components.

In this particular example, the electromagnetic component is a transformer, and the DC-bias current flowing through that transformer is translated / modulated by the switching stage, i.e. the active bridge, and will appear in the DC-link current having a component with the switching frequency as a fundamental frequency.

As shown in Figure 2, multiple methods can be applied to detect this harmonic component and may be categorized into at least two main types.

The first type relates to the series measurement. As shown in Fig. 2, the switching-frequency-harmonic component of the DC-link current $(i_{DC})_1$ can be measured by means of a series current sensor in the bridge's DC terminals. Hereafter in this disclosure, $(x)_h$ represents the h-th harmonic component of the variable $x(t)$.

The second type relates to a parallel measurement. The switching-frequency-harmonic harmonic component of the DC-link current $(i_{\mathrm{DC}})_1$ can be diverted

to a shunt path in the DC-link, and then used to determine a measure for the DC-bias current. This path may provide a low-impedance path for the harmonic current component, which is provided by the DC-link capacitor.

As a result, the current of the DC-link capacitor can be measured to detect a DC-bias current through the transformer. The resulting switching-frequency voltage ripple in the DC-link voltage V_1 can also be measured. For all these measurements, both active and passive analogue filters, or signal processing techniques can be used to extract the switching frequency component of the current and the voltage ripple of the DC-link, corresponding to a DC transformer current. Alternatively, additional circuitry can be used in the DC-link to partially divert the switching-frequency component of the DC-link current $(i_{\mathrm{DC}})_1$, and then detect the DC-bias current. This additional circuitry can be either a band-pass filter or a high-pass filter, depending on whether the second-order harmonic component $(i_{\mathrm{DC}})_2$ is desired to be attenuated.

As an example, a notch filter that is tuned to the switching frequency of the bridge can be placed in parallel with the DC-link capacitor C_{DC} to detect the switching-frequency-harmonic component $(i_{\mathrm{DC}})_1$. Fig. 3 shows the simplified representation of the converter under the DC-biased operation. The output terminals are left open, as they tend to present a high impedance at the switching frequency. The voltage v_{Lf} is the measured variable to detect the dc-bias current. If the respective resistances ESR and R_f of the DC-link capacitor and the inductor used in the notch filter are small, the transfer function of $G(s) = \frac{v_{Lf}}{(i_{\mathrm{DC}})_1}$ can be approximated as

$$G(s) = -\frac{ESR \cdot L_f s + \frac{L_f}{C_{\mathrm{DC}}}}{ESR + R_f + \frac{1}{C_{\mathrm{DC}} s} + \frac{1}{C_f s} + L_f s}$$

Fig. 4 shows the bode diagram of $G(s)$ for the circuit parameters that are provided in Table. 1.

Parameter	Definition	Value
f_s	Switching frequency	5 kHz
C_{DC}	DC-link capacitor	1 mF
ESR	Series resistance of DC-link Cap.	0.36 Ω

C_f	Capacitance of notch filter	470 nF
L_f	Inductance of notch filter	2.2 mH
R_f	Resistance of notch filter	0.7 Ω
f_r	Resonance frequency of notch filter	4.95 kHz

Table 1.

As shown in Fig. 5, in an example, the active bridge is realized as a full-bridge that switches to create an output voltage waveform with a duty cycle of *D*. Hence, the switching-frequency harmonic of the bridge current $(i_{DC})_1$ follows from

$$(i_{DC})_1 = \frac{4(\hat{I}_1)_0}{\pi} sin(\pi D)\, sin(\omega t),$$

where $(\hat{I}_1)_0$ and ω represent the amplitude of the DC component of i_1 and the angular switching frequency of the full-bridge, respectively.

As can be seen from Fig. 4, by setting the resonance frequency a bit lower than the switching frequency, the voltage $v_{Lf}(t)$ that appears across the filter inductor will have a phase shift of almost 180° with regard to $(i_{DC})_1$ and the phase of the filter is much less sensitive to frequency variation.

In addition to the first-order harmonic component and the other odd-order components, resulting from the DC-bias current, there are inherently even-order harmonic components in the filter inductor voltage, of which the second-order one may be predominant. As a result, the filter inductor voltage can be written as

$$v_{Lf}(t) = (\hat{V}_{Lf})_1 sin(\omega t + \varphi_1) + \sum_{h=2}^{\infty} (\hat{V}_{Lf})_h sin(h\omega t + \varphi_h)$$

Although the even-order components are attenuated by the notch filter, they can be a source of error when the filter inductor voltage is fed into a feedback loop for control of the transformer bias current. Since the undesired harmonics in the filter inductor voltage are of even order, they can be mitigated by sampling at the right moment.

Fig. 6 depicts the simulated waveform for the filter inductor voltage under a negative DC-bias current through the transformer. The inductor voltage can be sampled twice within each switching cycle at $\omega t = {}^{-\pi}/_{2}$ (S_1) and $\omega t = {}^{\pi}/_{2}$ (S_2) to remove the influence of the even-order frequency components on the measurements.

By subtracting two consecutive samples of the inductor voltage upon acquisition of the second sample S_2,

$$v_{fd}[n] = v_{Lf}[n-1] - v_{Lf}[n] = v_{Lf}\left(\omega t = \frac{-\pi}{2}\right) - v_{Lf}\left(\omega t = \frac{\pi}{2}\right)$$

$$= -2\sum_{h=0}^{\infty} (\hat{V}_{Lf})_{2h+1}\, cos(\varphi_{2h+1}),$$

the effect of even harmonics may then be mitigated. Here, the remaining term is proportional to the DC-bias current through the transformer, i.e. it is a measure for the DC-bias current. Hence, $v_{fd}[n]$ is fed into the feedback loop to actively compensate the DC-bias current.

Fig. 7 represents a possible implementation of the control loop to mitigate the DC-bias current through the transformer. The filter inductor voltage v_{Lf} is sampled at the middle of the positive and negative half-cycles of the bridge voltage v_1. The sampled values of these instances are subtracted upon acquisition of the second sample S_2, and the derived value is held until the next subtraction operation. The resulting variable v_{fd} which is linearly related to the DC-bias current is compared with the setpoint and fed into a PI controller. The output of this controller is the needed modification (Δd) in the duty cycle *(D)* of the PWM modulator to mitigate the DC voltage component in the bridge voltage.

Fig. 8 depicts the typical structure of a transformer-connected three-phase DC/AC converter. In principle, a similar concept applies in the three-phase converter to detect and mitigate DC-bias currents through the transformer windings. Here, the switching signals of phase legs {a, b, c} are shifted by 120° with regard to each other. Similar to the single-phase converter, the DC-bias currents $\{(i_a)_0, (i_b)_0, (i_c)_0\}$ through the transformer terminals will be modulated by the corresponding phase leg and added up as a switching-frequency-harmonic current component in the DC-link. The phase information of this harmonic component can indicate the required modification in the duty cycle of each phase leg to mitigate the DC-bias currents through the transformer windings.

To reduce the number of claims, certain aspects of the technology are presented below in certain claim forms, but the applicant contemplates the various aspects of the technology in any number of claim forms. For example, while some aspect of the technology may be recited as a computer-readable medium claim, other

aspects may likewise be embodied as a computer-readable medium claim, or in other forms, such as being embodied in a means-plus-function claim.

In the description above, for the purposes of explanation, numerous specific details are set forth in order to provide a thorough understanding of implementations of the disclosed technology. It will be apparent, however, to one skilled in the art that embodiments of the disclosed technology may be practiced without some of these specific details.

Other variations to the disclosed embodiments can be understood and effected by those skilled in the art in practicing the claimed invention, from a study of the drawings, the disclosure and the appended claims. In the claims, the word "comprising" does not exclude other elements or steps, and the indefinite article "a" or "an" does not exclude a plurality. The mere fact that certain measures are recited in mutually different dependent claims does not indicate that a combination of these measures cannot be used to advantage. Any reference signs in the claims should not be construed as limiting the scope thereof.

CONCLUSIES

1. Een schakelende vermogenselektronica-omvormer die is ingericht om een maat te bepalen voor een gelijkstroom-bias die door een elektromagnetische component stroomt, waarbij de schakelende vermogenselektronica-omvormer bestaat uit:

- een gelijkstroom, DC, linktrap om een gelijkspanning te leveren,
- een schakeltrap omvattende actieve schakelelementen, bediend met een schakelfrequentie, voor het omzetten van de gelijkspanning in een reeks spanningspulsen die aan de elektromagnetische component worden verschaft;
- de elektromagnetische component die direct of indirect is aangesloten op een schakelknooppunt van de schakeltrap;

waarin de schakelende vermogenselektronica-omvormer verder omvat:

- een gelijkstroom-bias stroomdetectietrap, verschaft in de DC-linktrap, waarin de gelijkstroom-bias stroomdetectiefase is ingericht om de maat voor de gelijkstroom-bias te bepalen door het bepalen van een stroom of spanning in de DC-linktrap met een frequentiecomponent op de schakelfrequentie.

2. Een schakelende vermogenselektronica-omvormer volgens conclusie 1, waarbij de gelijkstroom-bias stroomdetectietrapomvat een seriestroomsensor voor het bepalen van de stroom in de DC-linktrap die naar de schakeltrap stroomt.

3. Een schakelende vermogenselektronica-omvormer volgens een van de eerdere conclusies, waarbij de DC-linktrap een ingangscondensator omvat en waarin de gelijkstroom-bias stroomdetectietrap parallel aan de ingangscondensator is verschaft.

4. Een schakelende vermogenselektronica-omzetter volgens conclusie 3, waarbij de gelijkstroom-bias stroomdetectietrap een filter omvat dat is geassocieerd met de schakelfrequentie.

5. Een schakelende vermogenselektronica-omzetter volgens conclusie 4, waarbij het filter een banddoorlaatfilter en een hoogdoorlaatfilter is.

6. Een schakelende vermogenselektronica-omvormer volgens een van de eerdere conclusies, waarbij de schakelende vermogenselektronica-omvormer omvat:

- een DC-bias stuurcircuit dat is ingericht voor het sturen van de actieve schakelelementen op basis van de maat voor de gelijkstroom-bias.

7. Een schakelende vermogenselektronica-omzetter volgens conclusie 6, waarbij het DC-bias stuurcircuit omvat een analoog-naar-digitaal-omzetter, ADC, waarbij de ADC is ingericht om te bemonsteren met ten minste tweemaal de schakelfrequentie, zodat monsters met tweemaal de schakelfrequentie worden gebruikt.

8. Een schakelende vermogenselektronica-omvormer volgens een van de eerdere conclusies, waarbij de elektromagnetische component een van het volgende is:

- een inductor;
- een wikkeling van een transformator;
- een motorwikkeling;
- een actuatorwikkeling;
- een generatorwikkeling;
- een circuitinductie.

9. Een werkwijze voor het bedienen van een schakelende vermogenselektronica-omvormer volgens een van de voorgaande conclusies, waarbij de werkwijze de stappen omvat van:

- het bepalen, door middel van de gelijkstroom detectietrap, van de maat van de gelijkstroom-bias door het bepalen van een stroom, of spanning, in de DC-linktrap met een frequentiecomponent op de schakelfrequentie.

10. Een werkwijze volgens conclusie 9, waarbij de gelijkstroom-bias stroomdetectietrap een seriestroomsensor omvat en waarbij de werkwijze de stap omvat van:

- het bepalen, door middel van de seriestroomsensor, van de stroom in de gelijkstroom-bias stroomdetectietrap die naar de schakeltrap stroomt.

11. Een werkwijze volgens een van de conclusies 9 - 10, waarbij de DC-linktrap een ingangscondensator omvat en waarbij de gelijkstroom-bias stroomdetectietrap parallel aan de ingangscondensator is verschaft.

12. Een werkwijze volgens conclusie 11, waarbij de gelijkstroom-bias stroomdetectietrap omvat uit een filter dat geassocieerd is met de schakelfrequentie.

13. Een werkwijze volgens conclusie 12, waarbij het filter omvat een banddoorlaatfilter en een hoogdoorlaatfilter.

14. Een werkwijze volgens een van de conclusies 9 - 13, waarbij de schakelende vermogenselektronica-omvormer een DC-bias-regelcircuit omvat, waarbij de werkwijze de stap omvat van:

- het regelen, door middel van het DC-bias regelcircuit, van de actieve schakelelementen op basis van de maat van de gelijkstroom-bias.

15. Een werkwijze volgens conclusie 14, waarbij het DC-bias-regelcircuit omvat een analoog-naar-digitaal converter, ADC, waarbij de werkwijze de stap omvat van het:

- bemonsteren, door de ADC, met tweemaal de schakelfrequentie.

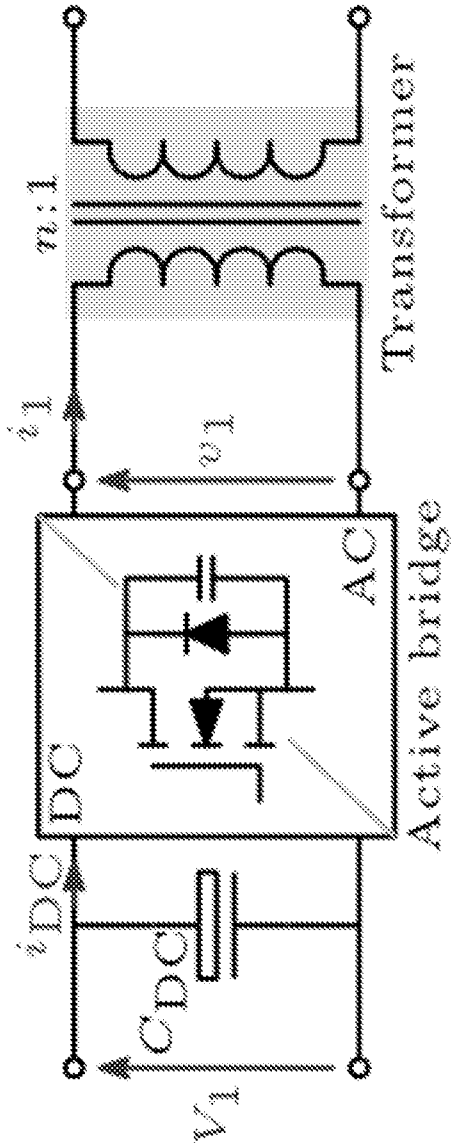


Fig. 1

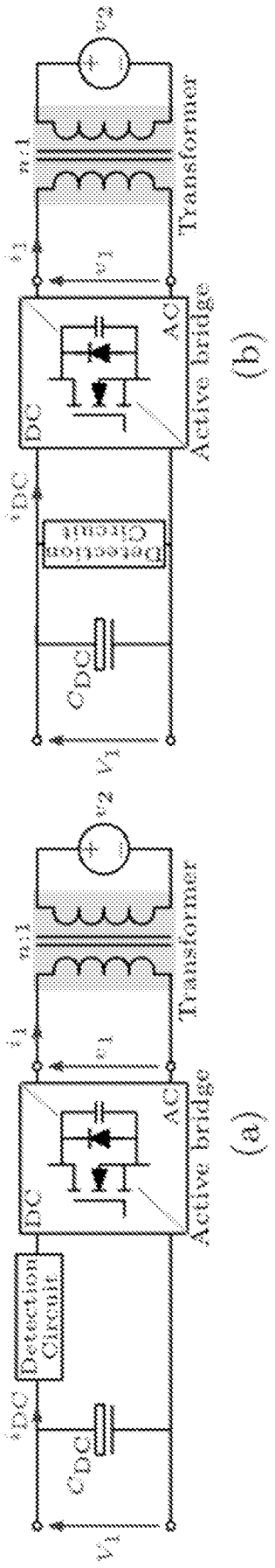

(a)
(b)
Transformer
Active bridge
AC
DC
Detection Circuit
n:1
v_2
v_1
i_1
i_{DC}
C_{DC}
V_1

Fig. 2

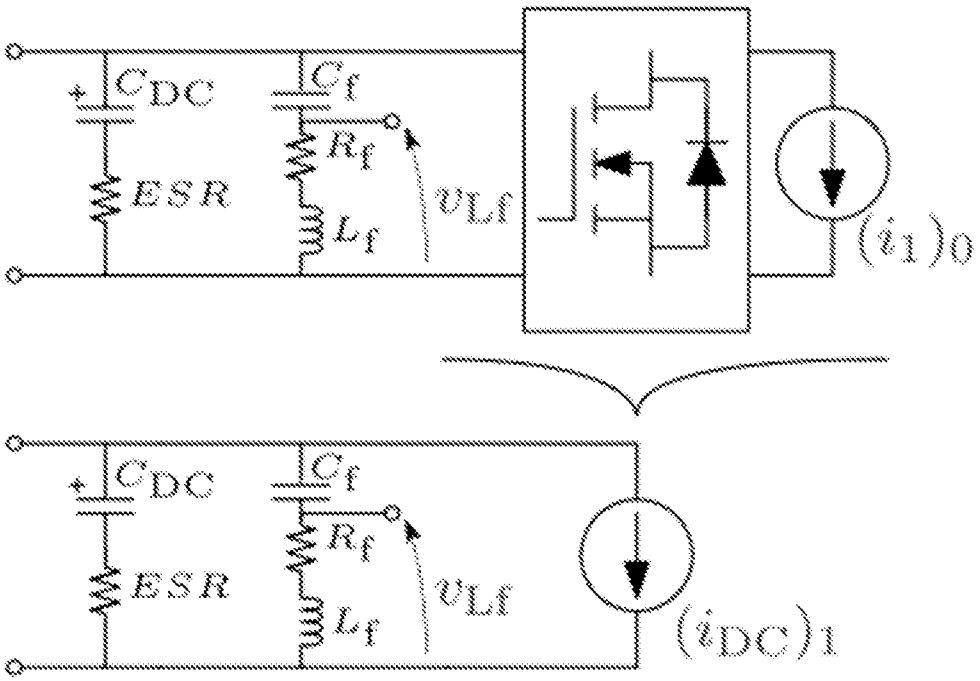


Fig. 3

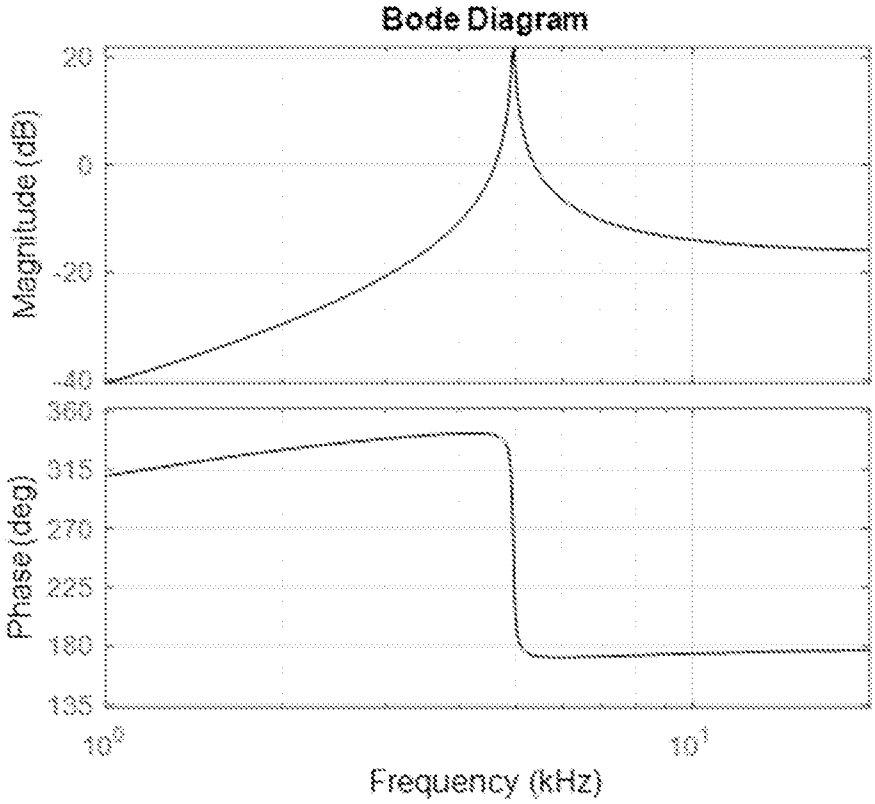

Bode Diagram
Magnitude (dB)
20
0
-20
-40
Phase (deg)
360
315
270
225
180
135
10^0
10^1
Frequency (kHz)

Fig. 4

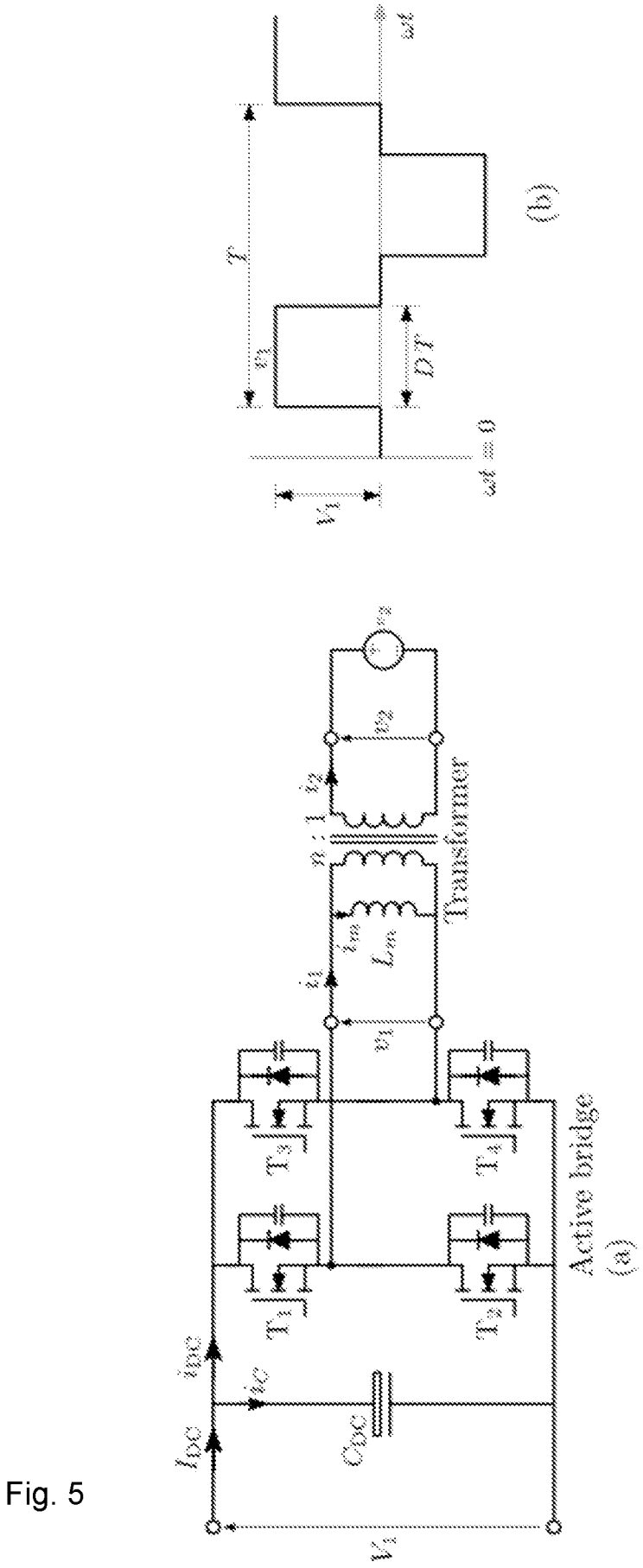


Fig. 5

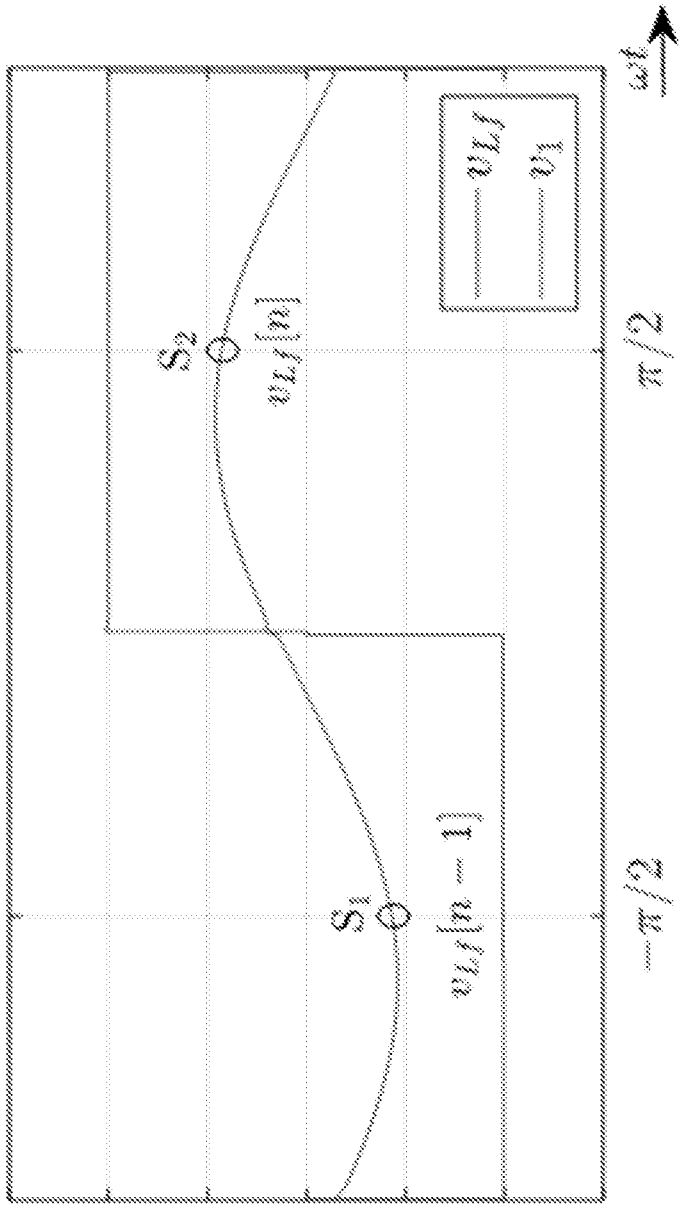


Fig. 6

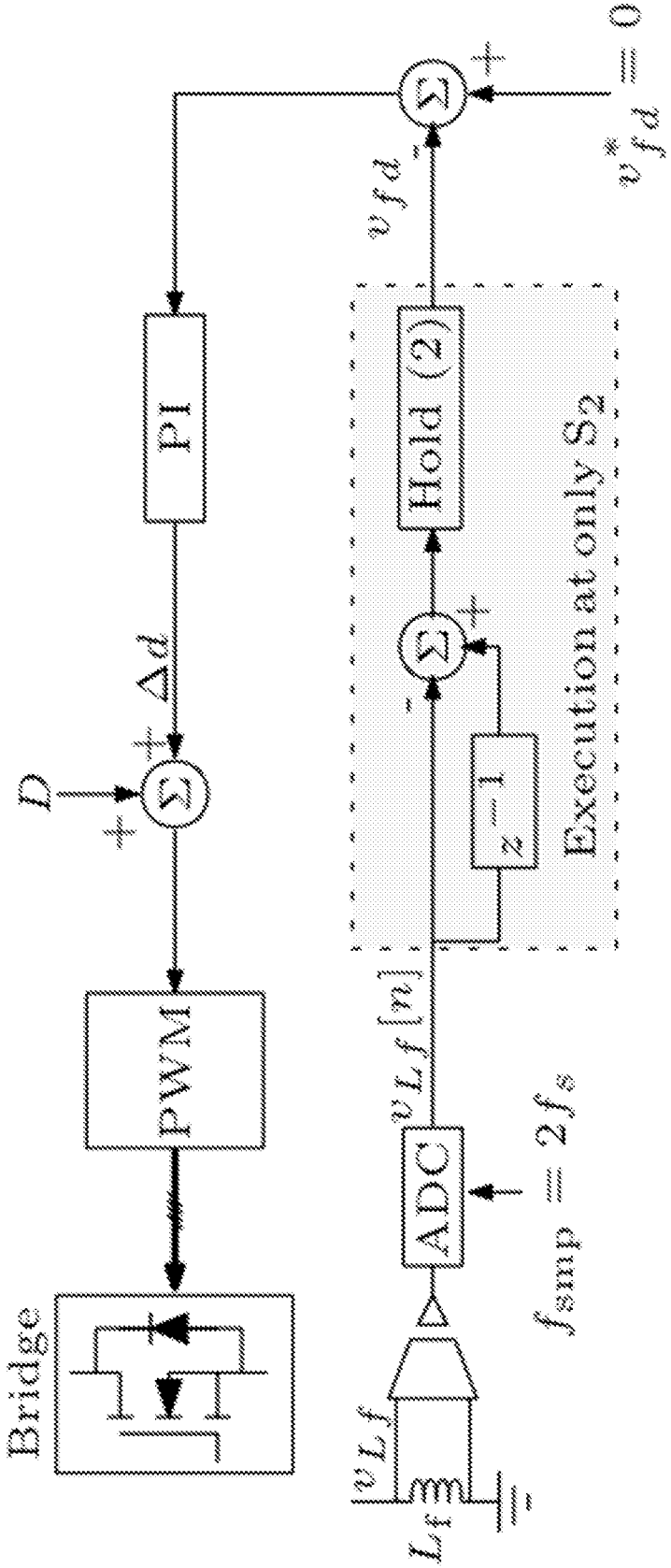

Bridge
PWM
PI
D
Δd
ADC
$v_{Lf}[n]$
$f_{samp} = 2f_s$
v_{Lf}
L_f
v_{fd}
$v^*_{fd} = 0$
Hold (2)
z^{-1}
Execution at only S_2

Fig. 7

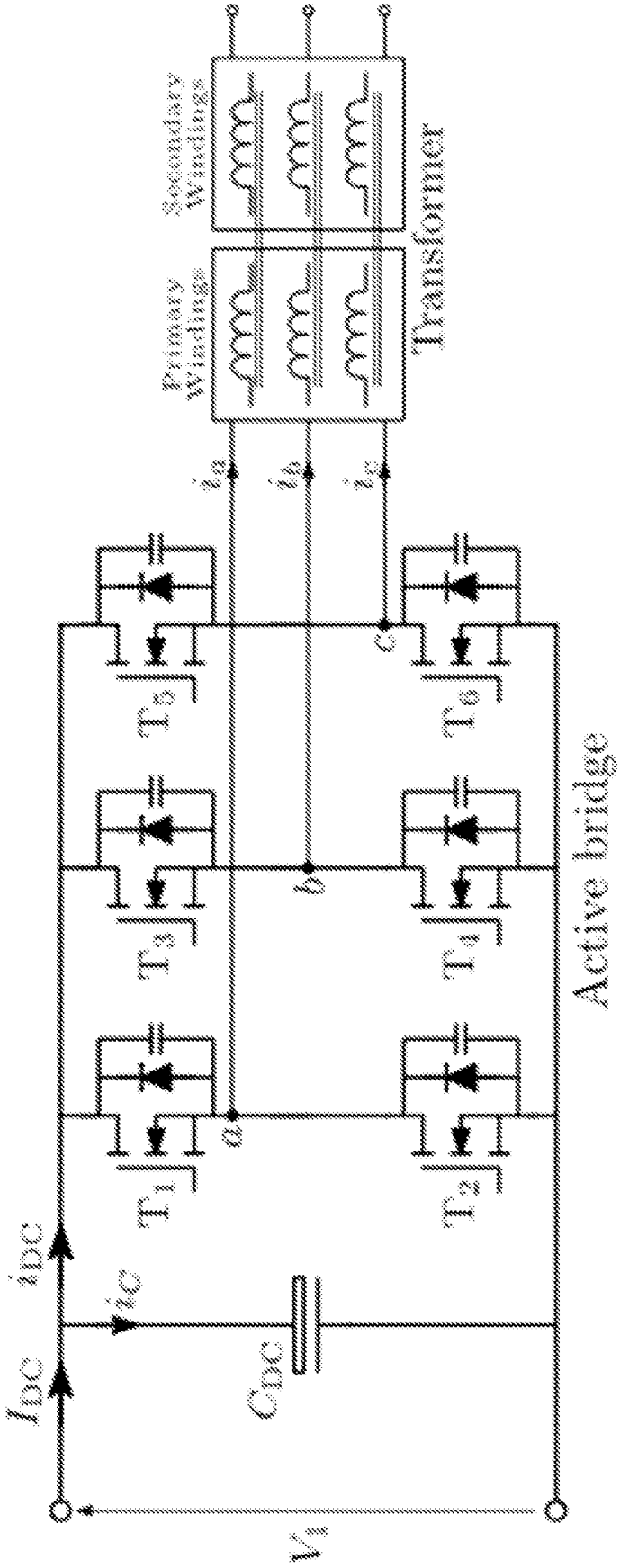

Secondary Winding
Primary Winding
Transformer
i_a
i_b
i_c
T_5
T_6
T_3
T_4
T_1
T_2
a
b
c
Active bridge
i_{DC}
i_C
C_{DC}
I_{DC}
V_{DC}

Fig. 8

Rijksdienst voor Ondernemend Nederland

OCTROOIAANVRAAG NR.:
NO 142847
NL 2034132

ONDERZOEKSRAPPORT

BETREFFENDE HET RESULTAAT VAN HET ONDERZOEK NAAR DE STAND VAN DE TECHNIEK

RELEVANTE LITERATUUR

Categorie[1]	Literatuur met, voor zover nodig, aanduiding van speciaal van belang zijnde tekstgedeelten of figuren.	Van belang voor conclusie(s) nr:	Classificatie(IPC)
X	JP H04 4762 A (FUJI ELECTRIC CO LTD) 9 januari 1992 (1992-01-09) * samenvatting *; figuren 1,2,3 *	1-15	INV. H02M1/00 ADD. H02M5/10 H02M3/335
X	JP 2021 083202 A (MITSUBISHI ELECTRIC CORP) 27 mei 2021 (2021-05-27) * samenvatting *; figuur 1 *	1-15	
A	JP 2022 110235 A (MEIDENSHA ELECTRIC MFG CO LTD) 29 juli 2022 (2022-07-29) * samenvatting * *	4,5,12, 13	

Onderzochte gebieden van de techniek: **H02M**

Indien gewijzigde conclusies zijn ingediend, heeft dit rapport betrekking op de conclusies ingediend op:

Plaats van onderzoek:	Datum waarop het onderzoek werd voltooid:	Bevoegd ambtenaar:
's-Gravenhage	**16 augustus 2023**	**Standaert, Frans**

[1] NDERLINCATEGORIE VAN DE VERMELDE LITERATUUR

X: de conclusie wordt als niet nieuw of niet inventief beschouwd ten opzichte van deze literatuur
Y: de conclusie wordt als niet inventief beschouwd ten opzichte van de combinatie van deze literatuur met andere geciteerde literatuur van dezelfde categorie, waarbij de combinatie voor de vakman voor de hand liggend wordt geacht
A: niet tot de categorie X of Y behorende literatuur die de stand van de techniek beschrijft
O: niet-schriftelijke stand van de techniek
P: tussen de voorrangsdatum en de indieningsdatum gepubliceerde literatuur
T: na de indieningsdatum of de voorrangsdatum gepubliceerde literatuur die niet bezwarend is voor de octrooiaanvrage, maar wordt vermeld ter verheldering van de theorie of het principe dat ten grondslag ligt aan de uitvinding
E: eerdere octrooi(aanvrage), gepubliceerd op of na de indieningsdatum, waarin dezelfde uitvinding wordt beschreven
D: in de octrooiaanvrage vermeld
L: om andere redenen vermelde literatuur
&: lid van dezelfde octrooifamilie of overeenkomstige octrooipublicatie

EOB FORM 02.83 (P0414B)

AANHANGSEL BEHORENDE BIJ HET RAPPORT BETREFFENDE HET ONDERZOEK NAAR DE STAND VAN DE TECHNIEK, UITGEVOERD IN DE OCTROOIAANVRAGE NR.

NO 142847
NL 2034132

Het aanhangsel bevat een opgave van elders gepubliceerde octrooiaanvragen of octrooien (zogenaamde leden van dezelfde octrooifamilie), die overeenkomen met octrooischriften genoemd in het rapport.
De opgave is samengesteld aan de hand van gegevens uit het computerbestand van het Europees Octrooibureau per
De juistheid en volledigheid van deze opgave wordt noch door het Europees Octrooibureau, noch door het Bureau voor de Industriële eigendom gegarandeerd;; de gegevens worden verstrekt voor informatiedoeleinden.

16-08-2023

In het rapport genoemd octrooigeschrift	Datum van publicatie	Overeenkomend(e) geschrift(en)	Datum van publicatie
JP H044762 A	09-01-1992	GEEN	
JP 2021083202 A	27-05-2021	JP 6858829 B1	14-04-2021
		JP 2021083202 A	27-05-2021
JP 2022110235 A	29-07-2022	GEEN	

EPO FORM P0466

Algemene informatie over dit aanhangsel is gepubliceerd in de 'Official Journal' van het Europees Octrooibureau nr 12/82 blz 448 ev

SCHRIFTELIJKE OPINIE

DOSSIER NUMMER	INDIENINGSDATUM	VOORRANGSDATUM	AANVRAAGNUMMER
NO142847	13.02.2023		NL2034132

CLASSIFICATIE
INV. H02M1/00 ADD. H02M5/10 H02M3/335

AANVRAGER
Technische Universiteit Eindhoven

Deze schriftelijke opinie bevat een toelichting op de volgende onderdelen:

- ☒ Onderdeel I Basis van de schriftelijke opinie
- ☐ Onderdeel II Voorrang
- ☐ Onderdeel III Vaststelling nieuwheid, inventiviteit en industriële toepasbaarheid niet mogelijk
- ☐ Onderdeel IV De aanvraag heeft betrekking op meer dan één uitvinding
- ☒ Onderdeel V Gemotiveerde verklaring ten aanzien van nieuwheid, inventiviteit en industriële toepasbaarheid
- ☐ Onderdeel VI Andere geciteerde documenten
- ☐ Onderdeel VII Overige gebreken
- ☒ Onderdeel VIII Overige opmerkingen

DE BEVOEGDE AMBTENAAR
Standaert, Frans

Aanvraag nr.:

SCHRIFTELIJKE OPINIE

NL2034132

Onderdeel I Basis van de Schriftelijke Opinie

1. Deze schriftelijke opinie is opgesteld op basis van de meest recente conclusies ingediend voor aanvang van het onderzoek.

2. Deze motivering is opgesteld, met betrekking tot **nucleotide- en/of aminozuursequenties** die genoemd worden in de aanvraag, op basis van een sequentielijst die:

   a. ☐ is opgenomen in de aanvraag zoals deze oorspronkelijk is ingediend

   b. ☐ aangeleverd is na de indieningsdatum ten behoeve van het onderzoek

      ☐ en vergezeld ging van een verklaring dat de sequentielijst niet meer informatie bevat dan de aanvraag zoals deze oorspronkelijk is ingediend.

3. ☐ Deze motivering is opgesteld, met betrekking tot nucleotide- en/of aminozuursequenties die genoemd worden in de aanvraag, voor zover een zinvolle motivering gevormd kon worden zonder een sequentielijst die voldeed aan WIPO standaard ST.26.

4. Overige opmerkingen:

Onderdeel V Gemotiveerde verklaring ten aanzien van nieuwheid, inventiviteit en industriële toepasbaarheid

1. Verklaring

Nieuwheid	Ja:	Conclusies	4, 5, 12, 13
	Nee:	Conclusies	1-3, 6-11, 14, 15
Inventiviteit	Ja:	Conclusies	
	Nee:	Conclusies	1-15
Industriële toepasbaarheid	Ja:	Conclusies	1-15
	Nee:	Conclusies	

2. Citaties en toelichting:

Zie aparte bladzijde

Onderdeel VIII Overige opmerkingen

De volgende opmerkingen met betrekking tot de duidelijkheid van de conclusies, beschrijving, en figuren, of met betrekking tot de vraag of de conclusies nawerkbaar zijn, worden gemaakt:

Zie aparte bladzijde

Re Item VIII

The features of the claims are not provided with reference signs placed in parentheses.

Re Item V

Reasoned statement with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

Reference is made to the following documents:

D1: JP H04 4762 A (FUJI ELECTRIC CO LTD) 9 januari 1992 (1992-01-09)

D2: JP 2021 083202 A (MITSUBISHI ELECTRIC CORP) 27 mei 2021 (2021-05-27)

D3: JP 2022 110235 A (MEIDENSHA ELECTRIC MFG CO LTD) 29 juli 2022

1 LACK OF NOVELTY

1.1 The present application does not meet the criteria of patentability, because the subject-matter of claims 1-3, 6-11, 14 and 15 is not new.

1.2 Document D1 discloses (the references in parentheses applying to this document):

Een schakelende vermogenselektronica-omvormer die is ingericht om een maat te bepalen voor een gelijkstroom-bias die door een elektromagnetische component stroomt (D1, Figs. 1, 2), waarbij de schakelende vermogenselektronica-omvormer bestaatuit:
een gelijkstroom, DC, linktrap (1) om een gelijkspanning te leveren, een schakeltrap (4, 5, 6, 7) omvattende actieve schakelelementen, bediend met een schakelfrequentie ("switching frequence", which is an inherent feature), voor het omzetten van de gelijkspanning in een reeks spanningspulsen die aan de elektromagnetische component (transformer 12) worden verschaft;
de elektromagnetische component die direct of indirect is aangesloten op een schakelknooppunt van de schakeltrap;
waarin de schakelende vermogenselektronica-omvormer verder omvat: een gelijkstroom-bias stroomdetectietrap (3, 20, 21, I_1, I_2, 22, biased magnetization detection unit 200), verschaft in de DC linktrap, waarin de gelijkstroom-bias stroomdetectiefase is ingericht om de maat voorde gelijkstroom-bias te bepalen door het bepalen van een stroom of spanning in de DC-linktrap met een frequentiecomponent op de schakelfrequentie (abstract).

The subject-matter of claim 1 is therefore not new.

1.3 The abstract and Fig. 1 of D1 also anticipate the subject-matter of dependent claims 3, 6, 8, 9, 11 and 14 (with regard to claim 9 it should also be noted that a machine translation of D1 shows that "the current Ic is detected by the current detector 20, and only the outflow current is extracted by the half-wave rectifier circuit 100 to form a detection waveform").

1.4 The subject-matter of claims 1, 2, 9 and 10 is known from for instance document D2 (abstract, Fig. 1).

1.5 For the subject-matter of dependent claims 7 and 15, see also Fig. 3 of D1, and note again that according to a machine translation of D1 "the current Ic is detected by the current detector 20, and only the outflow current is extracted by the half-wave rectifier circuit 100 to form a detection waveform".

2 LACK OF INVENTIVE STEP

2.1 The present application does not meet the criteria of patentability, because the subject-matter of claims 4, 5, 12 and 13 does not involve an inventive step.

This is because current detectors with filters for removing switching noise are well-known, see for instance the abstract of D3.