(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
04 May 2023 (04.05.2023)

WIPO | PCT

(10) International Publication Number
WO 2023/073584 A1

(51) International Patent Classification:
H02M 3/22 (2006.01) *H02M 3/335* (2006.01)

(21) International Application Number: PCT/IB2022/060299

(22) International Filing Date: 26 October 2022 (26.10.2022)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
63/272,422 27 October 2021 (27.10.2021) US

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(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CV, CZ, DE, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IQ, IR, IS, IT, JM, JO, JP, KE, KG, KH, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, WS, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, CV, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, ME, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Published:
— *with international search report (Art. 21(3))*
— *in black and white; the international application as filed contained color or greyscale and is available for download from PATENTSCOPE*

(54) Title: SYSTEM AND METHOD FOR MANAGING POWER DELIVERY TO A LOAD

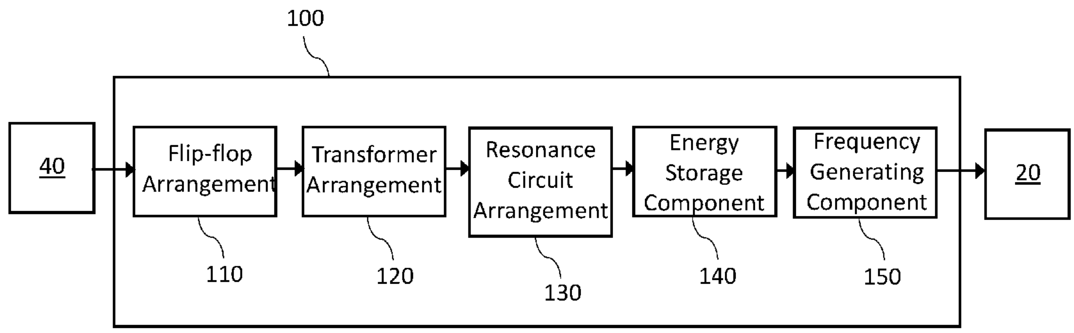

Figure 1

(57) Abstract: Power conversion system and method for delivering power to a load. The power conversion system electrically connecting between a DC power source and the load, and comprising at least one flip-flop arrangement for creating a first pulsed current having a first frequency, a transformer arrangement stepping up a potential of the first pulsed current, a first transformer portion of the transformer arrangement being connected to the at least one flip-flop arrangement, a resonance circuit arrangement connected to a second transformer portion of the transformer arrangement, the second transformer portion being in operation arrangement with the first transformer portion, the resonance circuit arrangement having a resonance frequency, and an energy storage component connected between the resonance circuit arrangement and the load when in use.

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SYSTEM AND METHOD FOR MANAGING POWER DELIVERY TO A LOAD

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] The present application claims priority to U.S. Patent Application No. 63/272,422, titled “SYSTEM AND METHOD FOR MANAGING POWER DELIVERY TO A LOAD”, filed October 27, 2021, the entirety of which is incorporated by reference herein.

TECHNICAL FIELD

[0001] The present disclosure relates to the field of electric power delivery from a power source and a load to be powered, and in particular to a power conversion system delivering pulsed electric current to the load to be powered.

BACKGROUND

[0002] A number of techniques have been developed to accomplish efficient power delivery. Most of them rely on delivering direct current (DC) or alternating current (AC) to apparatuses to be powered. However, little research has been directed to optimizing energy transmission between a power source and a load, and energy-efficient power conversion systems.

[0003] Indeed, it may be beneficial to optimize reception of electric power delivered by the power source and to manage said electric power in a power-efficient manner based on operation of the load. Consequently, power delivering techniques which can be implemented with less complexity and more efficiently are desirable.

[0004] There therefore remains a desire for improved power conversion systems for managing power delivery to a load.

SUMMARY

[0005] An aspect of the present disclosure is to provide a power conversion system for delivering power to a load, the system being configured for electrically connecting between a DC power source and the load, the system comprising at least one flip-flop arrangement for creating a first pulsed current having a first frequency; a transformer arrangement stepping up a potential of the first pulsed current, a first transformer portion of the transformer arrangement being connected to the at least one flip-flop arrangement; a resonance circuit arrangement connected to a second transformer portion of the transformer arrangement, the second transformer portion being in operation arrangement with the first transformer portion, the resonance circuit arrangement having a resonance frequency; and an energy storage component connected between the resonance circuit arrangement and the load when in use.

[0006] In at least one embodiment, the system further comprises at least one frequency generating component for creating a second pulsed current at a second frequency, the at least one frequency generating component being connected in series between the energy storage component and the load when the system is in use.

[0007] In at least one embodiment, the first frequency is greater than the second frequency.

[0008] In at least one embodiment, the first frequency is at least ten times greater than the second frequency.

[0009] In at least one embodiment, the at least one frequency generating component creating the second pulsed current comprises a transistor element; and a frequency generator.

[0010] In at least one embodiment, the first transformer portion is connected in series with the at least one flip-flop arrangement.

[0011] In at least one embodiment, the energy storage component is connected in parallel with the resonance circuit arrangement.

[0012] In at least one embodiment, the first frequency is set to be approximately equal to the resonance frequency of the resonance circuit arrangement.

[0013] In at least one embodiment, the first frequency is configured to be adjustable; and when in use, the first frequency being adjusted to be approximately equal to the resonance frequency of the resonance circuit arrangement.

[0014] In at least one embodiment, the resonance circuit arrangement comprises an inductor connected in series with the second transformer portion; and a capacitor connected in series with the inductor.

[0015] In at least one embodiment, the at least one flip-flop arrangement comprises a first flip-flop portion connected between a first end of the first transformer portion and a center of the first portion of the transformer arrangement; and a second flip-flop portion operating in collaboration with the first flip-flop portion, the second flip-flop portion being connected between a second end of the first transformer portion and the center of the first transformer portion.

[0016] In at least one embodiment, each of the first flip-flop portion and the second flip-flop portion comprises a switching device; and a frequency generator connected in series with the switching device.

[0017] In at least one embodiment, the switching device includes a MOSFET.

[0018] In at least one embodiment, the at least one flip-flop arrangement comprises a flip-flop device; a square-wave generator connected to the flip-flop device; a first switching device connected between a first end of the first portion of the transformer arrangement and a center of the first portion of the transformer arrangement, the first switching device being connected in series with the flip-flop device; and a second switching device connected between a second end of the first portion of the transformer arrangement and the center of the first portion of the transformer arrangement, the second switching device being connected in series with the flip-flop device and in parallel with the first switching device.

[0019] In at least one embodiment, the resonance circuit arrangement is connected in series to the second transformer portion.

[0020] In at least one embodiment, the energy storage component is at least one capacitor.

[0021] In at least one embodiment, the system further comprises at least one rectifier connected between the resonance circuit arrangement and the energy storage component.

[0022] In at least one embodiment, the at least one rectifier comprises at least one diode.

[0023] In at least one embodiment, the at least one rectifier comprises a diode bridge.

[0024] In at least one embodiment, the system is configured to be used for the load which is an apparatus operating by Joule effect; and the at least one frequency generating component for creating the second pulsed current at the second frequency is configured to provide short pulses to the apparatus.

[0025] In at least one embodiment, when in use, the DC power source is connected to a midpoint on a length of the first transformer portion.

[0026] According to another aspect of the present invention, there is provided a power conversion system for delivering power to a load, the system being configured for electrically connecting between a DC power source and the load, the system comprising at least one flip-flop arrangement for creating a first pulsed current having a first frequency; a transformer arrangement stepping up a potential of the first pulsed current, a first transformer portion of the transformer arrangement being connected to the at least one flip-flop arrangement; a resonance circuit arrangement connected to a second transformer portion of the transformer arrangement, the second transformer portion being in operation arrangement with the first transformer portion, the resonance circuit arrangement having a resonance frequency; an energy storage component connected between the resonance circuit arrangement and the load when in use; a pair of secondary transformer arrangements, each secondary transformer arrangement comprising a first transformer portion connected in series with the second portion of the transformer arrangement, a second transformer portion operatively arranged with the first transformer, and a diode bridge connected in series with the second transformer portion; and at least one feedback energy storage component connected to the pair of secondary transformer arrangements, the at least one feedback energy storage component being configured to be connected in parallel with the DC power source when in use.

[0027] In at least one embodiment, the system further comprises at least one frequency generating component for creating a second pulsed current at a second frequency, the at least one frequency generating component being connected in series between the energy storage component and the load when the system is in use.

[0028] In at least one embodiment, the system further comprises at least one frequency generating component for creating a second pulsed current at a second frequency, the at least one frequency generating component being connected in series between the energy storage component and the load when the system is in use.

[0029] In at least one embodiment, the first frequency is greater than the second frequency.

[0030] In at least one embodiment, the first frequency is at least ten times greater than the second frequency.

[0031] In at least one embodiment, the at least one frequency generating component creating the second pulsed current comprises a transistor element; and a frequency generator.

[0032] In at least one embodiment, the first transformer portion is connected in series with the at least one flip-flop arrangement.

[0033] In at least one embodiment, the energy storage component is connected in parallel with the resonance circuit arrangement.

[0034] In at least one embodiment, the resonance circuit arrangement is connected in series with the second transformer portion.

[0035] In at least one embodiment, the at least one feedback energy storage device includes a first capacitor, a pulse generator operatively connected to the first capacitor, and a second capacitor connected to the pulse generator; and when in use, the DC power source is connected in parallel with the second capacitor.

[0036] In at least one embodiment, the system is configured to be used for the load which is an apparatus operating by Joule effect; and the at least one frequency generating component for creating the second pulsed current at the second frequency is configured to provide short pulses to the apparatus.

[0037] In at least one embodiment, when in use, the DC power source is connected to a midpoint on a length of the first transformer portion.

[0038] According to yet another aspect of the present invention, there is provided a method for delivering power to a load, the method being performed by a power conversion system electrically connected between a DC power source and the load, the method comprising creating a first pulsed current by at least one flip-flop arrangement of the system, the first pulsed current having a first frequency; stepping up a potential of the first pulsed current using a transformer arrangement of the system; increasing the potential of the first pulsed current using a resonance circuit arrangement of the system, the first frequency being approximately equal to a resonance frequency of the resonance circuit arrangement; storing energy, by an energy storage component, from the transformed first pulsed current; supplying power to the load from the energy storage component.

[0039] In at least one embodiment, the method further comprises rectifying, by a rectifier of the system, the first pulsed current prior to storing the energy to the capacitor.

[0040] In at least one embodiment, the method further comprises creating a second pulsed current by at least one frequency generating component, the second pulsed current having a second frequency; and supplying the second pulsed current to the load, the second frequency being configured for use by the load.

[0041] In at least one embodiment, supplying the second pulsed current to the load includes supplying a short, rectified pulsed current to the load, the load being an apparatus operating by Joule effect.

[0042] In at least one embodiment, the method further comprises collecting, by a pair of secondary transformer arrangements connected to the transformer arrangement of the system, at least some losses of the resonance circuit arrangement; and returning at least a portion of energy of the at least some losses to the at least one flip-flop arrangement.

[0043] In at least one embodiment, the method further comprises measuring an estimated resonance harmonic frequency of the resonance circuit arrangement; and adjusting the flip-flop arrangement such that the first frequency is approximately equal to the estimated resonance harmonic frequency.

BRIEF DESCRIPTION OF THE FIGURES

[0044] The features and advantages of the present disclosure will become apparent from the following detailed description, taken in combination with the appended drawings, in which:

[0045] Figure 1 is a block diagram of a power conversion system for managing power delivery according to an embodiment of the present technology;

[0046] Figure 2 is an electrical diagram of a circuit of the power conversion system of Figure 1 according to an embodiment of the present technology;

[0047] Figure 3 is an electrical diagram of a circuit of the power conversion system of Figure 1 according to another embodiment of the present technology; and

[0048] Figure 4 illustrates a flow diagram showing operations of a method for managing power delivery to a load to be powered in accordance with an embodiment of the present technology.

[0049] It is to be understood that throughout the appended drawings and corresponding descriptions, like features are identified by like reference characters. Furthermore, it is also to be understood that the drawings and ensuing descriptions are intended for illustrative purposes only and that such disclosures are not intended to limit the scope of the claims.

DETAILED DESCRIPTION

[0050] Various representative embodiments of the disclosed technology will be described more fully hereinafter with reference to the accompanying drawings, in which representative embodiments are shown. The presently disclosed technology may, however, be embodied in many different forms and should not be construed as limited to the representative embodiments set forth herein. Rather, these representative embodiments are provided so that the disclosure will be thorough and complete, and will fully convey the scope of the present technology to those skilled in the art. In the drawings, the sizes and relative sizes of layers and regions may be exaggerated for clarity. Like numerals refer to like elements throughout. And, unless otherwise defined, all technical and scientific terms used herein have the same meaning as commonly understood by one of ordinary skill in the art to which the described embodiments pertain.

[0051] Various aspects of the present disclosure generally address one or more of the problems found in conventional power supplies. To this end, the present disclosure introduces a power conversion system connecting a DC power source to a load. In a first embodiment, the power conversion system comprises a frequency generating component (e.g a flip-flop arrangement) for creating a first pulsed current having a first frequency. A transformer arrangement further steps up a potential of the first alternating current. In this embodiment, a first transformer portion of the transformer arrangement is connected to the frequency generating component. A resonance circuit arrangement is connected to a second transformer portion of the transformer arrangement, the second transformer portion being in operation arrangement with the first transformer portion. An energy storage component is connected between the resonance circuit arrangement and the load when in use, such that the load may receive electric energy from the energy storage.

[0052] Generally speaking, loads which are used for thermal energy generation (e.g. heaters) are typically supplied with DC or AC current, such that the generation of thermal energy is due to the Joule effect. In one non-limiting embodiment, the power conversion system of the present disclosure enables delivering pulsed current to the load in a power-efficient manner such that a duration between two consecutive pulses delivered to the load is relatively small compared to a characteristic time of temperature variation of the load.

[0053] Referring now to the drawings, Figure 1 is a block diagram of a power conversion system 100 electrically connecting a DC voltage supply 40 to a load 20 according to an embodiment of the present technology. The DC voltage supply 40 may, for example and without limitation, provide a voltage V_0 between 12V and 120V. In this embodiment, the power conversion system 100 comprises a flip-flop arrangement 110 that is energized with V_0. The flip-flop arrangement 110 generates a pulsed current having a first frequency f_1. As an example, the first frequency f_1 may be set between 3kHz and 20kHz. The pulsed current is then directed to a first portion of a transformer arrangement 120 of the power conversion system 100. In this embodiment, the transformer arrangement 120 is configured to increase the voltage (*i.e.* electrical potential, V) between the first portion and a second portion thereof by a factor N. As an example, N may be set to 100. As such, the second portion of the transformer arrangement 120 is energized under a voltage $V_1=V_0.N$.

[0054] The second portion of the transformer arrangement 120 is electrically connected to a resonance circuit arrangement 130 having a resonance frequency f_R. In this embodiment and as it will be described in greater details hereafter, the first frequency of the flip-flop arrangement 110 may be adjusted to be set approximately equal to the resonance frequency f_R. As such, the voltage at an output of the resonance circuit arrangement 130 is increased. The power conversion system 100 further comprises an energy storage component 140 electrically connected at the output of the resonance circuit arrangement 130 and configured to store electrical energy from the current flowing from the resonance circuit arrangement 130. Electrical energy is thus delivered from the energy storage component 140 to the load 20 via a frequency generating component 150. In this embodiment, the load 20 is an apparatus operating by the Joule effect.

[0055] Figure 2 is a schematic diagram of a circuit of the power conversion system 100 according to a non-limiting embodiment of the present technology. In this embodiment, the DC voltage supply 40 to which the power conversion system 100 is connected is represented as a combination of an ideal voltage supply 1 electrically connected to a resistor 2. At its input, the power conversion system 100 comprises a capacitor 3 electrically connected to the flip-flop arrangement 110. In this embodiment, the flip-flop arrangement 110 comprises a first frequency generator 5 and a second frequency generator 8, each of the first and second frequency generator 5, 8 being coupled to a Metal Oxide Semiconductor Field Effect Transistor (MOSFET) for generating a first pulsed current. Use of any other transistor elements or switching device instead of the MOSFETs to perform the functions of the MOSFETs described herein is contemplated in alternative embodiments. More specifically, the flip-flop arrangement comprises a “flip” part and a “flop” part. The flip part comprises the first frequency generator 5, a MOSFET 4 and a resistor 6. The “flop” part comprises the first frequency generator 8, a MOSFET 7 and a resistor 9.

[0056] Each of the MOSFETs 4,7 has a drain, a gate electrically connected to its respective one of the first and second frequency generators 5, 8, and a source. The MOSFETs 4, 7 act as transistors whose resistance may be adjusted based on the voltage applied at their gates by their respective frequency generator. In this embodiment, the first and second frequency generators 5, 8 may deliver square waves with an amplitude of 5V at the first frequency f_1, the signals of the first and second frequency generators 5, 8 having 180° phase difference. In use, each MOSFET 4, 7 is alternatively turned on (i.e. closed) to allow the current to flow from the DC voltage supply

40 to the transformer arrangement 120. As the frequency generators 5, 8 respectively cause their MOSFETs 4, 7 to open and close at the first frequency f_1, the transformer arrangement 120 receives a first pulsed current at the frequency f_1.

[0057] More specifically, in this embodiment, the transformer arrangement 120 comprises a first portion receiving the first pulsed current, the first portion comprising a first coil portion 10 and a second coil portion 11 electrically connected to the first coil portion 10. The DC voltage supply 40 is electrically connected to the first portion of the transformer arrangement 120 at a connection between the first and second coil portions 10, 11 such as to form a center-tapped transformer. As such, in response to the MOSFET 4 being closed and the MOSFET 7 being open, the current flows through the first coil portion 10 and though the MOSFET 4. Similarly, in response to the MOSFET 7 being closed and the MOSFET 4 being open, the current flows through the second coil portion 11 and through the MOSFET 7. Pulses are thereby generated in the first portion of the transformer arrangement 120.

[0058] The transformer arrangement 120 comprises a second portion comprising a coil 12. As an example, in this embodiment, the turns ratio of the transformer arrangement 120 is set such that the potential V_S at the second portion of the transformer arrangement 120 is 100 higher than the potential V_P at the first portion of the transformer arrangement 120. More specifically, the number of turns N_P at the first portion (i.e. addition of turns of the first and second coil portion 10 ,11) and the number of turns N_S at the second portion are set such that: $\frac{N_S}{N_P} = \frac{V_S}{V_P} = 100$. The turns ratio $\frac{N_S}{N_P}$ may be different in alternative embodiments.

[0059] In use, the first pulsed current flowing in the first portion of the transformer arrangement 120 induces, via a magnetic field of the first and second coil portion 10, 11, an induced current in the second portion of the transformer arrangement 120. In the context of the present, the induced current is also referred to as the “first current”. It should thus be understood that the first current flows through transformer arrangement 120, the transformer arrangement 120 stepping up the potential of the first current at the between the first and second coil portion 10, 11 and the coil 12.

[0060] Terminals of the coil 12 are connected to the resonance circuit arrangement 130 such that the first pulsed current may flow therein. In this embodiment, the resonance circuit arrangement 130 comprises a coil 13 and a capacitor 14 connected in parallel (i.e. LC circuit) and has the resonance frequency f_R. The first frequency f_1 of the frequency generators 5, 8 of the frequency generating component 110 is set approximately equal to the resonance frequency f_R to increase the potential at the capacitor 14. In an embodiment, an estimated resonance harmonic frequency of the resonance circuit arrangement 130 may be measured (e.g. based on impendences of the coil 13 and the capacitor 14) and the first frequency of the frequency generators 5, 8 may be adjusted accordingly.

[0061] The power conversion system 100 may comprise a diode 15 for rectifying the first pulsed current. The second current may be then directed to the energy storage component 140 being, in this embodiment, implemented as a capacitor 16. In this embodiment, the energy storage component 140 is connected in parallel with the resonance circuit arrangement 130.

[0062] In this embodiment, the frequency generating component 150 of the power conversion system 100 comprises a frequency generator 19, a MOSFET 18 and a resistor 17. The frequency generator 19 may generate a square wave with an amplitude of 5V at a second frequency f_2 that may be, for example and without limitation, set at 60Hz approximately. In this embodiment, the first frequency f_1 is greater (e.g. a hundred times greater) than the second frequency f_2. As such, by alternatively opening and closing the MOSFET 18, the frequency generator 19 causes the energy stored in the capacitor 16 to pulsed to the load 20 at the frequency f_2, thereby creating a second pulsed current flowing from the capacitor 16 to the load 20.

[0063] Figure 3 is a schematic diagram of a circuit of a power conversion system 200 according to another non-limiting embodiment of the present technology. Elements of the system 200 that are similar to those of the system 100 retain the same reference numeral and will generally not be described again.

[0064] In this embodiment, the frequency generating component comprises a single frequency generator 21 generating a square wave signal with, for example, an amplitude of 5V at the first frequency f_1, and a SR latch 22. The SR latch 22 may facilitate alternating openings of the

MOSFETs 4, 7. Indeed, the SR latch 22 automatically causes closing of one of the first and second MOSFETs 4, 7 in response to opening another one of the first and second MOSFETs 4, 7.

[0065] Additionally, in this embodiment, the power conversion system 200 further comprises a second transformer arrangement 23 electrically connecting the second portion of the transformer arrangement 120 to the resonance circuit arrangement 130. More specifically, the second transformer arrangement 23 comprises a pair of secondary transformer arrangements, each one of the secondary transformer arrangements being electrically connected to one of the terminals of the coil 12 of the second portion of the transformer arrangement 120.

[0066] In this embodiment, each one of the pair of secondary transformer arrangements collect energy from the first pulsed current flowing from the transformer arrangement 120 to the resonance circuit arrangement 130. A first secondary transformer arrangement includes a coil L5 electrically connected to the coil 12 of the transformer arrangement 120 and the coil 13 of the resonance circuit arrangement 130. The first secondary transformer arrangement further includes a coil L4 coupled to the coil L5 such that the first pulsed current flowing in the coil L5 induces a first induced current in L4. The first induced current is then directed to a first diode bridge formed by four diodes D1, D2, D3 and D4 of the first secondary transformer arrangement. The power conversion system further includes feedback energy storage component implanted, in this embodiment, as a capacitor 25, to store electrical energy of the second transformer arrangement 23. As such, the first induced current is rectified by the first diode bridge before its energy is stored in the capacitor 25.

[0067] Similarly, in this embodiment, a second secondary transformer arrangement comprises a coil L7 electrically connected to the coil 12 of the transformer arrangement 120 and the capacitor 14 of the resonance circuit arrangement 130 (i.e. at a terminal of the resonance circuit opposite to the first secondary transformer arrangement). The second secondary transformer arrangement further comprises a coil L6 coupled to the coil L7 such that the first pulsed current flowing in the coil L7 induces a second induced current in L6. The second induced current is then directed to a second diode bridge formed by four diodes D5, D6, D7 and D8 of the second secondary transformer arrangement. The second induced current is further rectified by the second diode bridge before its energy is stored in the capacitor 25.

[0068] In the embodiment of system 200, the capacitor 25 is electrically connected to a frequency generating component 160 comprising a MOSFET, a resistor and a frequency generator that may deliver, for example and without limitation, square waves with an amplitude of 5V at the first frequency f_1.

[0069] As such, by alternatively opening and closing the MOSFET of the frequency generating component 160, said frequency generator generates, in collaboration with the capacitor 25, a third pulsed current flowing from the capacitor 25 to the capacitor 3, such that electrical energy may be reintroduced in the flip-flop arrangement 110 of the power conversion system via connection lines *a* and *b*. It can be said that the second transformer arrangement 23 may thus collect at least some losses of the resonance circuit arrangement 130 occurring at an input thereof. Connection line *a* includes a diode to prevent the DC voltage supply 40 from directly providing current to the capacitor 25.

[0070] In the illustrative embodiment of Figure 3, the diode 15 of system 100 has been replaced by a diode bridge 15 formed by four diodes D9, D10, D11 and D12 such that the first pulsed current is rectified before being received by the energy storage component 140 (i.e. the capacitor 16).

[0071] With reference to Figure 4, a method 400 for delivering power to the load 20, the method being performed by the power conversion system 100 electrically connecting the DC power source 10 to the load 20, according to some implementations of the present technology is illustrated in the form of a flow chart. In one or more aspects, the method 400 or one or more step thereof may be performed by the power conversion system 100. It is also contemplated that the method 400 could be performed by the system 200, *mutatis mutandis*. In some implementations, one of more steps of the method 400 could be implemented, whole or in part, by another electronic device. Some steps or portions of steps in the flow diagram may be possibly being executed concurrently, omitted or changed in order.

[0072] The method 400 begins with creating, at step 405, the first pulsed current by the flip-flop arrangement 110, the first pulsed current having a first frequency f_1. In this embodiment and as described hereabove, the flip-flop arrangement 110 may be implemented as a single frequency generator, such as the frequency generator 21, delivering square waves to a SR latch, such as SR latch 22, to control two alternatively activated MOSFETs, such as MOSFETs 4, 7.

[0073] The method 400 continues with stepping up, at step 410, the potential of the first pulsed using the transformer arrangement 120. In this embodiment, the transformer arrangement 120 is a center-tapped transformer having a turns ratio set at approximately 100.

[0074] The method 400 continues with increasing, at step 415, the potential of the first pulsed current using the resonance circuit arrangement 130. Such increase is caused by adjustment of the first frequency f_1 approximately equal to the resonance frequency f_R of the resonance circuit arrangement 130. As an example, the method 400 may include measuring an estimated resonance harmonic frequency of the resonance circuit arrangement 130 and adjusting the frequency generator of the flip-flop arrangement 110 such that the first frequency f_1 is approximately equal to the estimated resonance harmonic frequency f_R.

[0075] The method 400 continues with storing, at step 420, energy from the now transformed first pulsed current by the energy storage component 140. In this embodiment, the first pulsed current is directed to the capacitor 16 after having been rectified by the diode bridge formed by the diodes D9 , D10, D11 and D12.

[0076] In this embodiment, the method 400 may further include collecting, by the second transformer arrangement 23, and more specifically by the pair of secondary transformer arrangements coupled to the transformer arrangement 120 of the system, at least some losses of the resonance circuit arrangement and returning at least a portion of energy of the at least some losses to the at least one flip-flop arrangement 110.

[0077] The method 400 then terminates with supplying, at step 425, power from the energy storage component 140 to the load 20. In at least some embodiments, said supplying includes creating, at sub-step 427, the second pulsed current by at least one frequency generating component, such as the frequency generator 19 in collaboration with the MOSFET 18 of the frequency generating component 150, the second pulsed current having the second frequency f_2. The method 400 may further include supplying, at sub-step 429, the second pulsed current to the load 20, the second frequency being configured for use by the load 20. As such, the load 20 is supplied with a short, rectified pulsed current.

[0078] While the above-described implementations have been described and shown with reference to particular steps performed in a particular order, it will be understood that these steps may be combined, sub-divided, or re-ordered without departing from the teachings of the present technology. At least some of the steps may be executed in parallel or in series. Accordingly, the order and grouping of the steps is not a limitation of the present technology.

[0079] It is to be understood that the operations and functionality of the described power conversion systems 100, 200, their constituent components, and associated processes may be achieved by any one or more of hardware-based elements. Such operational alternatives do not, in any way, limit the scope of the present disclosure.

[0080] As such, the methods and systems implemented in accordance with some non-limiting embodiment of the present technology can be represented as follows, presented in numbered clauses.

Clauses

[Clause 1] A power conversion system for delivering power to a load, the system being configured for electrically connecting between a DC power source and the load, the system comprising:

at least one flip-flop arrangement for creating a first pulsed current having a first frequency;

a transformer arrangement stepping up a potential of the first pulsed current, a first transformer portion of the transformer arrangement being connected to the at least one flip-flop arrangement;

a resonance circuit arrangement connected to a second transformer portion of the transformer arrangement,

the second transformer portion being in operation arrangement with the first transformer portion, the resonance circuit arrangement having a resonance frequency; and an energy storage component connected between the resonance circuit arrangement and the load when in use.

[Clause 2] The system of clause 1, further comprising at least one frequency generating component for creating a second pulsed current at a second frequency, the at least one frequency generating component being connected in series between the energy storage component and the load when the system is in use.

[Clause 3] The system of clause 2, wherein the first frequency is greater than the second frequency.

[Clause 4] The system of clause 2 or 3, wherein the first frequency is at least ten times greater than the second frequency.

[Clause 5] The system of any one of clauses 2 to 4, wherein the at least one frequency generating component creating the second pulsed current comprises:

a transistor element; and

a frequency generator.

[Clause 6] The system of any one of clauses 1 to 5, wherein the first transformer portion is connected in series with the at least one flip-flop arrangement.

[Clause 7] The system of any one of clauses 1 to 6, wherein the energy storage component is connected in parallel with the resonance circuit arrangement.

[Clause 8] The system of any one of clauses 1 to 7, wherein the first frequency is set to be approximately equal to the resonance frequency of the resonance circuit arrangement.

[Clause 9] The system of any one of clauses 1 to 8, wherein:

the first frequency is configured to be adjustable; and

when in use, the first frequency being adjusted to be approximately equal to the resonance frequency of the resonance circuit arrangement.

[Clause 10] The system of any one of clauses 1 to 9, wherein the resonance circuit arrangement comprises:

an inductor connected in series with the second transformer portion; and

a capacitor connected in series with the inductor.

[Clause 11] The system of any one of clauses 1 to 10, wherein the at least one flip-flop arrangement comprises:

a first flip-flop portion connected between a first end of the first transformer portion and a center of the first portion of the transformer arrangement; and

a second flip-flop portion operating in collaboration with the first flip-flop portion, the second flip-flop portion being connected between a second end of the first transformer portion and the center of the first transformer portion.

[Clause 12] The system of clause 11, wherein each of the first flip-flop portion and the second flip-flop portion comprises:

a switching device; and

a frequency generator connected in series with the switching device.

[Clause 13] The system of clause 12, wherein the switching device includes a MOSFET.

[Clause 14] The system of any one of clauses 1 to 13, wherein the at least one flip-flop arrangement comprises:

a flip-flop device;

a square-wave generator connected to the flip-flop device;

a first switching device connected between a first end of the first portion of the transformer arrangement and a center of the first portion of the transformer arrangement,

the first switching device being connected in series with the flip-flop device; and a second switching device connected between a second end of the first portion of the transformer arrangement and the center of the first portion of the transformer arrangement,

the second switching device being connected in series with the flip-flop device and in parallel with the first switching device.

[Clause 15] The system of any one of clauses 1 to 14, wherein the resonance circuit arrangement is connected in series to the second transformer portion.

[Clause 16] The system of any one of clauses 1 to 15, wherein the energy storage component is at least one capacitor.

[Clause 17] The system of any one of clauses 1 to 16, further comprising at least one rectifier connected between the resonance circuit arrangement and the energy storage component.

[Clause 18] The system of clause 17, wherein the at least one rectifier comprises at least one diode.

[Clause 19] The system of clause 17 or 18, wherein the at least one rectifier comprises a diode bridge.

[Clause 20] The system of any one of clauses 1 to 19, wherein:

the system is configured to be used for the load which is an apparatus operating by Joule effect; and

the at least one frequency generating component for creating the second pulsed current at the second frequency is configured to provide short pulses to the apparatus.

[Clause 21] The system of any one of clauses 1 to 20, wherein, when in use, the DC power source is connected to a midpoint on a length of the first transformer portion.

[Clause 22] A power conversion system for delivering power to a load, the system being configured for electrically connecting between a DC power source and the load, the system comprising:

at least one flip-flop arrangement for creating a first pulsed current having a first frequency;

a transformer arrangement stepping up a potential of the first pulsed current, a first transformer portion of the transformer arrangement being connected to the at least one flip-flop arrangement;

a resonance circuit arrangement connected to a second transformer portion of the transformer arrangement,

the second transformer portion being in operation arrangement with the first transformer portion, the resonance circuit arrangement having a resonance frequency;

an energy storage component connected between the resonance circuit arrangement and the load when in use;

a pair of secondary transformer arrangements, each secondary transformer arrangement comprising:

a first transformer portion connected in series with the second portion of the transformer arrangement,

a second transformer portion operatively arranged with the first transformer, and

a diode bridge connected in series with the second transformer portion; and

at least one feedback energy storage component connected to the pair of secondary transformer arrangements, the at least one feedback energy storage component being configured to be connected in parallel with the DC power source when in use.

[Clause 23] The system of clause 22, further comprising at least one frequency generating component for creating a second pulsed current at a second frequency, the at least one frequency generating component being connected in series between the energy storage component and the load when the system is in use.

[Clause 24] The system of clause 22 or 23, further comprising at least one frequency generating component for creating a second pulsed current at a second frequency, the at least one frequency generating component being connected in series between the energy storage component and the load when the system is in use.

[Clause 25] The system of clause 24, wherein the first frequency is greater than the second frequency.

[Clause 26] The system of clause 25, wherein the first frequency is at least ten times greater than the second frequency.

[Clause 27] The system of any one of clauses 24 to 26, wherein the at least one frequency generating component creating the second pulsed current comprises:

a transistor element; and

a frequency generator.

[Clause 28] The system of any one of clauses 22 to 27, wherein the first transformer portion is connected in series with the at least one flip-flop arrangement.

[Clause 29] The system of any one of clauses 22 to 28, wherein the energy storage component is connected in parallel with the resonance circuit arrangement.

[Clause 30] The system of any one of clauses 22 to 29, wherein the resonance circuit arrangement is connected in series with the second transformer portion.

[Clause 31] The system of any one of clauses 22 to 30, wherein:

the at least one feedback energy storage device includes:

a first capacitor,

a pulse generator operatively connected to the first capacitor, and

a second capacitor connected to the pulse generator; and when in use, the DC power source is connected in parallel with the second capacitor.

[Clause 32] The system of any one of clauses 22 to 31, wherein:

the system is configured to be used for the load which is an apparatus operating by Joule effect; and

the at least one frequency generating component for creating the second pulsed current at the second frequency is configured to provide short pulses to the apparatus.

[Clause 33] The system of any one of clauses 22 to 32, wherein, when in use, the DC power source is connected to a midpoint on a length of the first transformer portion.

[Clause 34] A method for delivering power to a load, the method being performed by a power conversion system electrically connected between a DC power source and the load, the method comprising:

creating a first pulsed current by at least one flip-flop arrangement of the system, the first pulsed current having a first frequency;

stepping up a potential of the first pulsed current using a transformer arrangement of the system;

increasing the potential of the first pulsed current using a resonance circuit arrangement of the system, the first frequency being approximately equal to a resonance frequency of the resonance circuit arrangement;

storing energy, by an energy storage component, from the transformed first pulsed current;

supplying power to the load from the energy storage component.

[Clause 35] The method of clause 34, further comprising rectifying, by a rectifier of the system, the first pulsed current prior to storing the energy to the capacitor.

[Clause 36] The method of clause 34 or 35, further comprising:

creating a second pulsed current by at least one frequency generating component, the second pulsed current having a second frequency; and

supplying the second pulsed current to the load, the second frequency being configured for use by the load.

[Clause 37] The method of any one of clauses 34 to 36, wherein supplying the second pulsed current to the load includes supplying a short, rectified pulsed current to the load, the load being an apparatus operating by Joule effect.

[Clause 38] The method of any one of clauses 34 to 37, further comprising:

collecting, by a pair of secondary transformer arrangements connected to the transformer arrangement of the system, at least some losses of the resonance circuit arrangement; and

returning at least a portion of energy of the at least some losses to the at least one flip-flop arrangement.

[Clause 39] The method of any one of clauses 34 to 38, further comprising:

measuring an estimated resonance harmonic frequency of the resonance circuit arrangement; and

adjusting the flip-flop arrangement such that the first frequency is approximately equal to the estimated resonance harmonic frequency.

[0081] It will be understood that, although the embodiments presented herein have been described with reference to specific features and structures, it is clear that various modifications and combinations may be made without departing from such disclosures. The specification and drawings are, accordingly, to be regarded simply as an illustration of the discussed implementations or embodiments and their principles as defined by the appended claims, and are contemplated to cover any and all modifications, variations, combinations or equivalents that fall within the scope of the present disclosure.

WHAT IS CLAIMED IS:

1. A power conversion system for delivering power to a load, the system being configured for electrically connecting between a DC power source and the load, the system comprising:

at least one flip-flop arrangement for creating a first pulsed current having a first frequency;

a transformer arrangement stepping up a potential of the first pulsed current, a first transformer portion of the transformer arrangement being connected to the at least one flip-flop arrangement;

a resonance circuit arrangement connected to a second transformer portion of the transformer arrangement,

the second transformer portion being in operation arrangement with the first transformer portion, the resonance circuit arrangement having a resonance frequency; and

an energy storage component connected between the resonance circuit arrangement and the load when in use.

2. The system of claim 1, further comprising at least one frequency generating component for creating a second pulsed current at a second frequency, the at least one frequency generating component being connected in series between the energy storage component and the load when the system is in use.

3. The system of claim 2, wherein the first frequency is greater than the second frequency.

4. The system of claim 3, wherein the first frequency is at least ten times greater than the second frequency.

5. The system of any one of claims 2 to 4, wherein the at least one frequency generating component creating the second pulsed current comprises:

a transistor element; and

a frequency generator.

6. The system of any one of claims 1 to 5, wherein the first transformer portion is connected in series with the at least one flip-flop arrangement.

7. The system of any one of claims 1 to 6, wherein the energy storage component is connected in parallel with the resonance circuit arrangement.

8. The system of any one of claims 1 to 7, wherein the first frequency is set to be approximately equal to the resonance frequency of the resonance circuit arrangement.

9. The system of any one of claims 1 to 8, wherein:

the first frequency is configured to be adjustable; and

when in use, the first frequency being adjusted to be approximately equal to the resonance frequency of the resonance circuit arrangement.

10. The system of any one of claims 1 to 9, wherein the resonance circuit arrangement comprises:

an inductor connected in series with the second transformer portion; and

a capacitor connected in series with the inductor.

11. The system of any one of claims 1 to 10, wherein the at least one flip-flop arrangement comprises:

a first flip-flop portion connected between a first end of the first transformer portion and a center of the first portion of the transformer arrangement; and

a second flip-flop portion operating in collaboration with the first flip-flop portion, the second flip-flop portion being connected between a second end of the first transformer portion and the center of the first transformer portion.

12. The system of claim 11, wherein each of the first flip-flop portion and the second flip-flop portion comprises:

a switching device; and

a frequency generator connected in series with the switching device.

13. The system of claim 12, wherein the switching device includes a MOSFET.

14. The system of any one of claims 1 to 13, wherein the at least one flip-flop arrangement comprises:

a flip-flop device;

a square-wave generator connected to the flip-flop device;

a first switching device connected between a first end of the first portion of the transformer arrangement and a center of the first portion of the transformer arrangement,

the first switching device being connected in series with the flip-flop device; and

a second switching device connected between a second end of the first portion of the transformer arrangement and the center of the first portion of the transformer arrangement, the second switching device being connected in series with the flip-flop device and in parallel with the first switching device.

15. The system of any one of claims 1 to 14, wherein the resonance circuit arrangement is connected in series to the second transformer portion.

16. The system of any one of claims 1 to 15, wherein the energy storage component is at least one capacitor.

17. The system of any one of claims 1 to 17, further comprising at least one rectifier connected between the resonance circuit arrangement and the energy storage component.

18. The system of claim 17, wherein the at least one rectifier comprises at least one diode.

19. The system of claim 17, wherein the at least one rectifier comprises a diode bridge.

20. The system of any one of claims 1 to 19, wherein:

the system is configured to be used for the load which is an apparatus operating by Joule effect; and

the at least one frequency generating component for creating the second pulsed current at the second frequency is configured to provide short pulses to the apparatus.

21. The system of any one of claims 1 to 20, wherein, when in use, the DC power source is connected to a midpoint on a length of the first transformer portion.

22. A power conversion system for delivering power to a load, the system being configured for electrically connecting between a DC power source and the load, the system comprising:

at least one flip-flop arrangement for creating a first pulsed current having a first frequency;

a transformer arrangement stepping up a potential of the first pulsed current, a first transformer portion of the transformer arrangement being connected to the at least one flip-flop arrangement;

a resonance circuit arrangement connected to a second transformer portion of the transformer arrangement,

the second transformer portion being in operation arrangement with the first transformer portion, the resonance circuit arrangement having a resonance frequency;

an energy storage component connected between the resonance circuit arrangement and the load when in use;

a pair of secondary transformer arrangements, each secondary transformer arrangement comprising:

a first transformer portion connected in series with the second portion of the transformer arrangement,

a second transformer portion operatively arranged with the first transformer, and

a diode bridge connected in series with the second transformer portion; and

at least one feedback energy storage component connected to the pair of secondary transformer arrangements, the at least one feedback energy storage component being configured to be connected in parallel with the DC power source when in use.

23. The system of claim 22, further comprising at least one frequency generating component for creating a second pulsed current at a second frequency, the at least one frequency generating component being connected in series between the energy storage component and the load when the system is in use.

24. The system of claim 22 or 23, further comprising at least one frequency generating component for creating a second pulsed current at a second frequency, the at least one frequency generating component being connected in series between the energy storage component and the load when the system is in use.

25. The system of claim 24, wherein the first frequency is greater than the second frequency.

26. The system of claim 25, wherein the first frequency is at least ten times greater than the second frequency.

27. The system of any one of claims 24 to 26, wherein the at least one frequency generating component creating the second pulsed current comprises:

a transistor element; and

a frequency generator.

28. The system any one of claims 22 to 27, wherein the first transformer portion is connected in series with the at least one flip-flop arrangement.

29. The system of any one of claims 22 to 28, wherein the energy storage component is connected in parallel with the resonance circuit arrangement.

30. The system of any one of claims 22 to 29, wherein the resonance circuit arrangement is connected in series with the second transformer portion.

31. The system of any one of claims 22 to 30, wherein:

the at least one feedback energy storage device includes:

a first capacitor,

a pulse generator operatively connected to the first capacitor, and

a second capacitor connected to the pulse generator; and

when in use, the DC power source is connected in parallel with the second capacitor.

32. The system of any one of claims 22 to 31, wherein:

the system is configured to be used for the load which is an apparatus operating by Joule effect; and

the at least one frequency generating component for creating the second pulsed current at the second frequency is configured to provide short pulses to the apparatus.

33. The system of any one of claims 22 to 32, wherein, when in use, the DC power source is connected to a midpoint on a length of the first transformer portion.

34. A method for delivering power to a load, the method being performed by a power conversion system electrically connected between a DC power source and the load, the method comprising:

creating a first pulsed current by at least one flip-flop arrangement of the system, the first pulsed current having a first frequency;

stepping up a potential of the first pulsed current using a transformer arrangement of the system;

increasing the potential of the first pulsed current using a resonance circuit arrangement of the system, the first frequency being approximately equal to a resonance frequency of the resonance circuit arrangement;

storing energy, by an energy storage component, from the transformed first pulsed current;

supplying power to the load from the energy storage component.

35. The method of claim 34, further comprising rectifying, by a rectifier of the system, the first pulsed current prior to storing the energy to the capacitor.

36. The method of claim 34 or 35, further comprising:

creating a second pulsed current by at least one frequency generating component, the second pulsed current having a second frequency; and supplying the second pulsed current to the load, the second frequency being configured for use by the load.

37. The method of any one of claims 34 to 36, wherein supplying the second pulsed current to the load includes supplying a short, rectified pulsed current to the load, the load being an apparatus operating by Joule effect.

38. The method of any one of claims 34 to 37, further comprising:

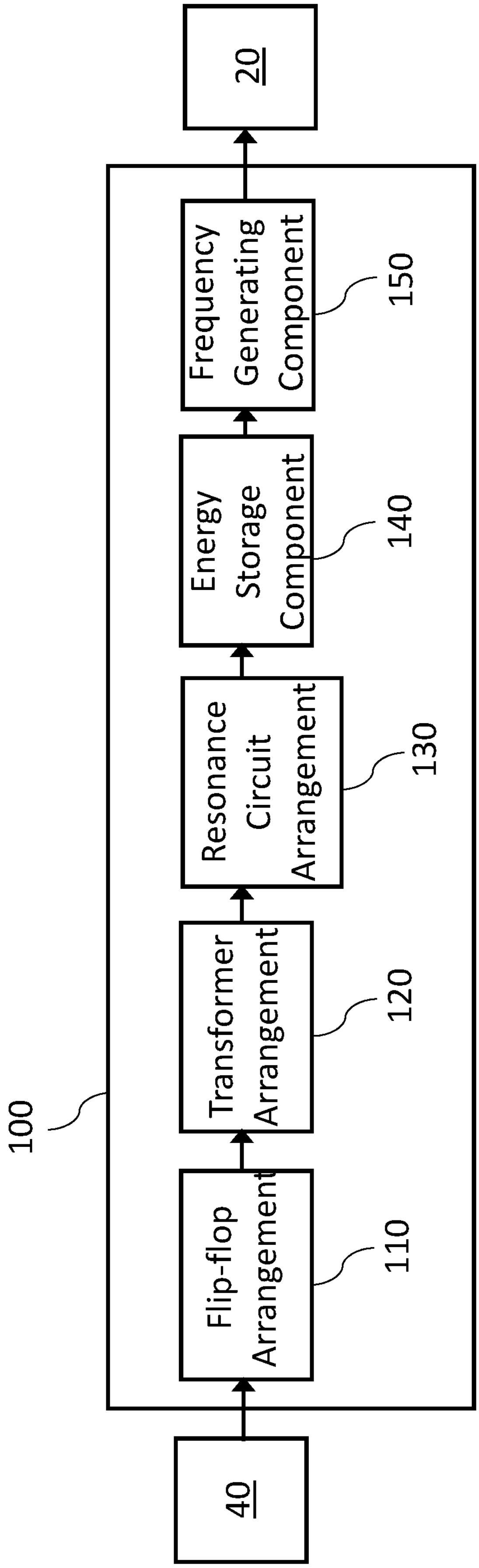
collecting, by a pair of secondary transformer arrangements connected to the transformer arrangement of the system, at least some losses of the resonance circuit arrangement; and

returning at least a portion of energy of the at least some losses to the at least one flip-flop arrangement.

39. The method of any one of claims 34 to 38, further comprising:

measuring an estimated resonance harmonic frequency of the resonance circuit arrangement; and

adjusting the flip-flop arrangement such that the first frequency is approximately equal to the estimated resonance harmonic frequency.


20
Frequency Generating Component
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Energy Storage Component
140
Resonance Circuit Arrangement
130
Transformer Arrangement
120
100
Flip-flop Arrangement
110
40

Figure 1

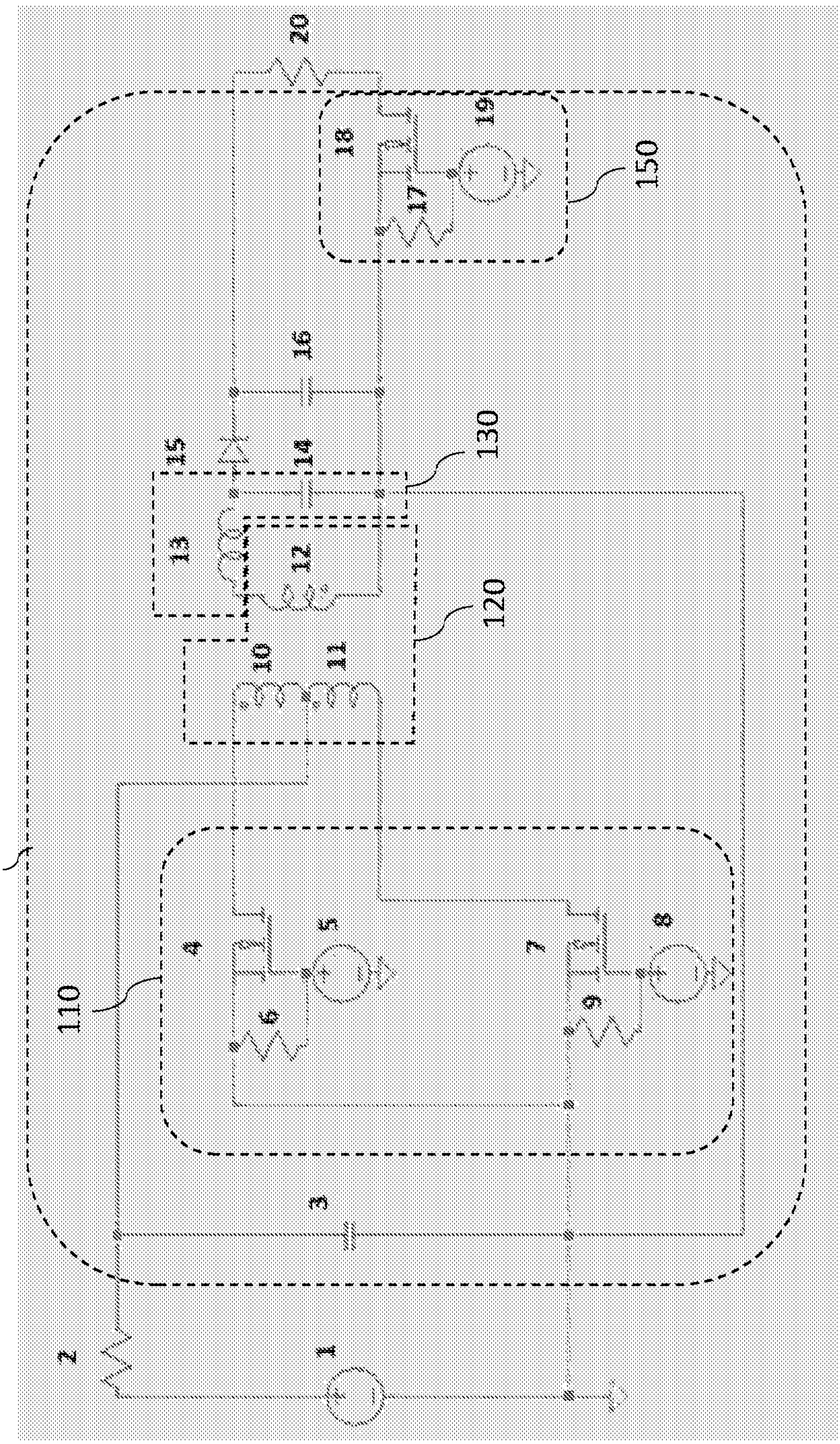
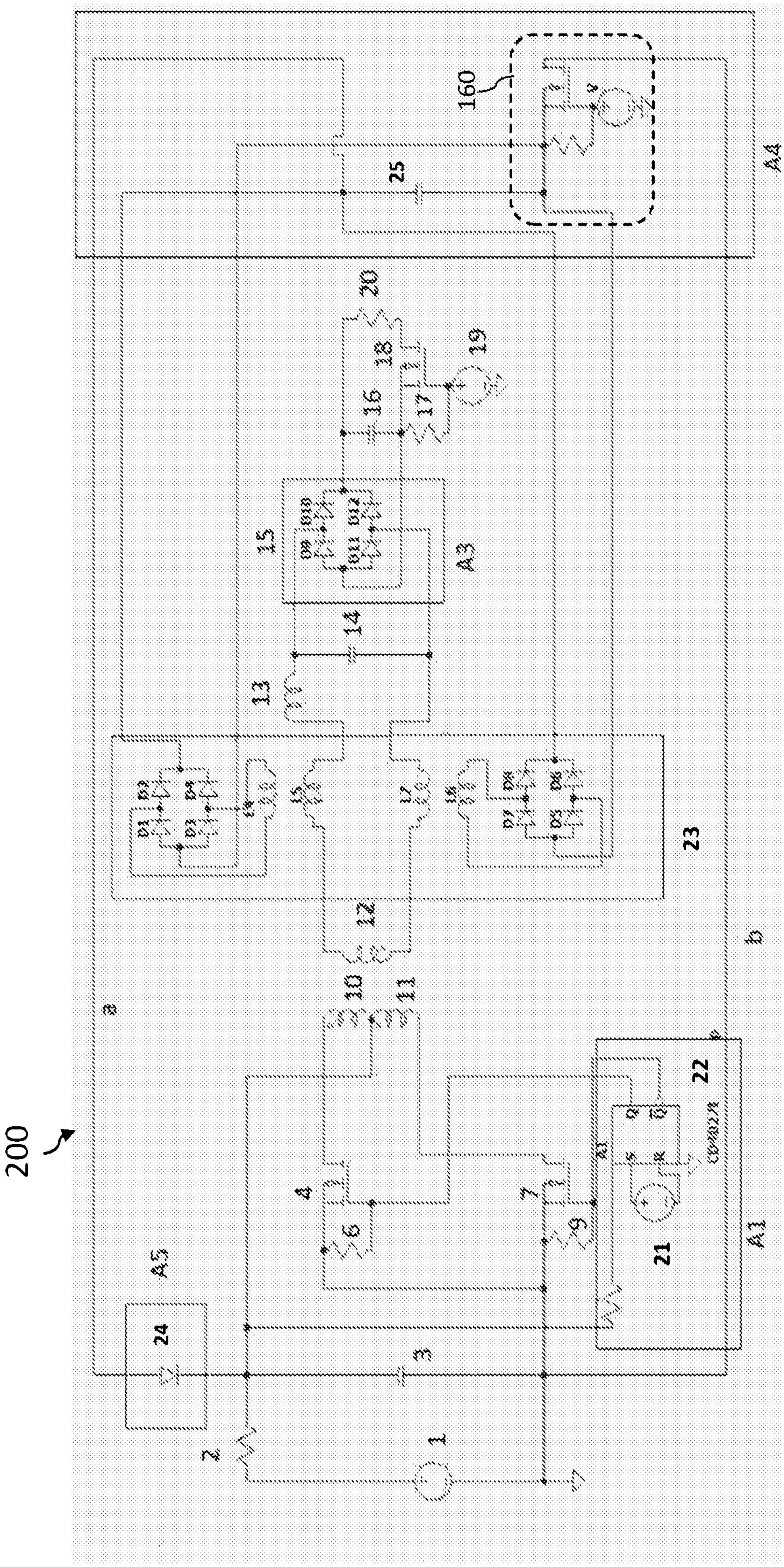


Figure 2


200
160
A1
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A5
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a
b

Figure 3

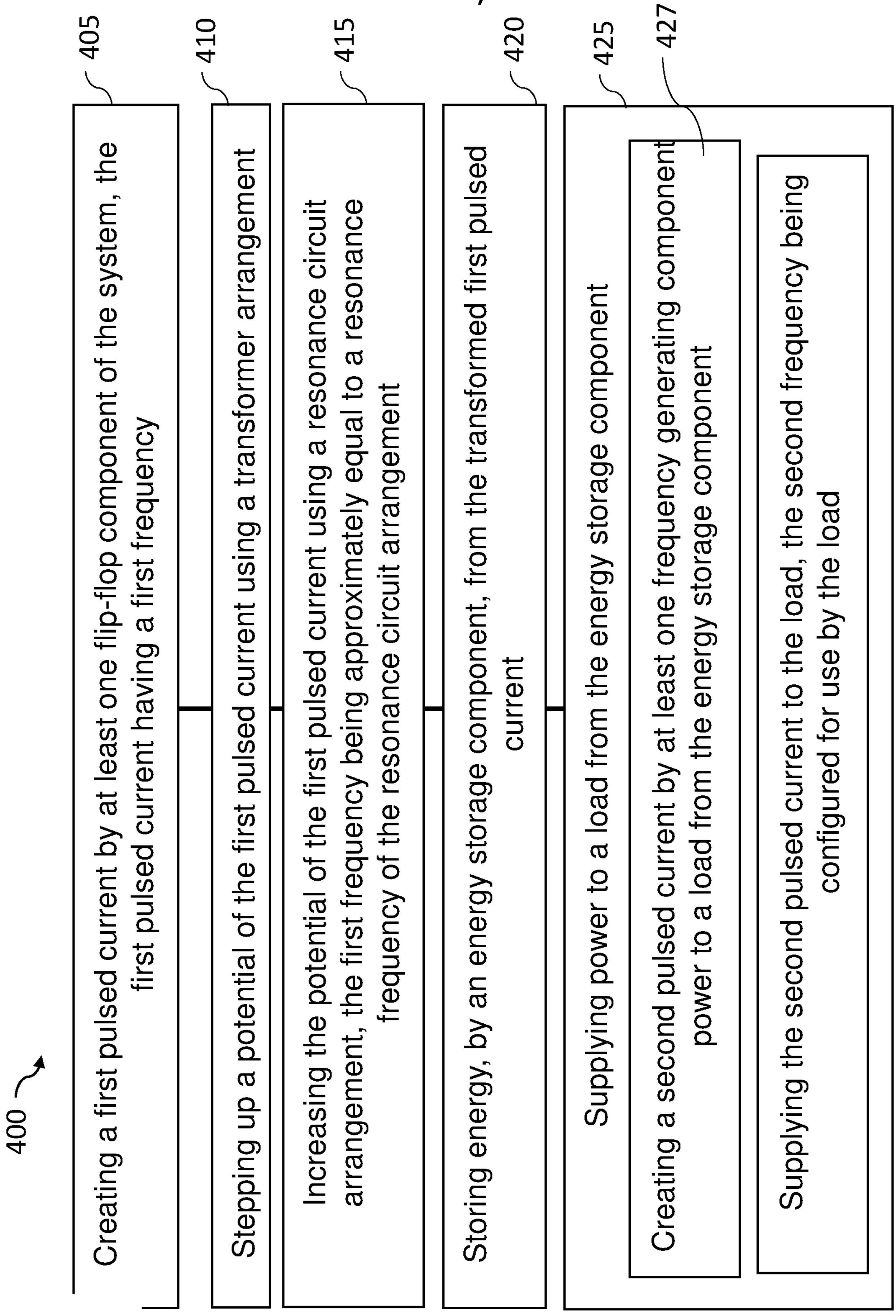
400
405
Creating a first pulsed current by at least one flip-flop component of the system, the first pulsed current having a first frequency
410
Stepping up a potential of the first pulsed current using a transformer arrangement
415
Increasing the potential of the first pulsed current using a resonance circuit arrangement, the first frequency being approximately equal to a resonance frequency of the resonance circuit arrangement
420
Storing energy, by an energy storage component, from the transformed first pulsed current
425
Supplying power to a load from the energy storage component
427
Creating a second pulsed current by at least one frequency generating component power to a load from the energy storage component
Supplying the second pulsed current to the load, the second frequency being configured for use by the load

Figure 4

INTERNATIONAL SEARCH REPORT

International application No.
PCT/IB2022/060299

A. CLASSIFICATION OF SUBJECT MATTER

IPC: ***H02M 3/22*** (2006.01) , ***H02M 3/335*** (2006.01)

CPC: **H02M 3/22** (2020.01) , H02M 3/01 (2021.05) , H02M 3/335 (2020.01)

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC: H02M 3/22 (2006.01), H02M 3/335 (2006.01) and CPC: H02M 3/22 (2020.01), H02M 3/01 (2021.05), H02M 3/335 (2020.01)

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

Electronic database(s) consulted during the international search (name of database(s) and, where practicable, search terms used)
Databases: Questel-Orbit (FamPat), Google Patents, IEEE Xplore, Scopus
Keywords: power, conversion, system, DC, power, source, load, flip, flop, current, pulsed, transformer, resonance, circuit, energy, delivering, electric, Joule, effect, arrangement, portion, capacitor, secondary, winding, switching, loss, storage, frequency, generat*, thermal.

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US20210305901A1 (ZHU, N.) 30 September 2021 (30-09-2021) *Abstract; par. [0002], [0036]-[0050], [0064]; FIGs. 1-2*	1-19, 21-30, and 33-36
Y	US20130314951A1 (HARRISON, M.) 28 November 2013 (28-11-2013) *par. [007]-[0012]; [0033]-[0039]; FIGs. 1-4E*	1-19, 21-30, and 33-36
A	US20090251925A1 (USUI, H. et al.) 08 October 2009 (08-10-2009) *whole document*	1-39

☒ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

*	Special categories of cited documents:
"A"	document defining the general state of the art which is not considered to be of particular relevance
"D"	document cited by the applicant in the international application
"E"	earlier application or patent but published on or after the international filing date
"L"	document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O"	document referring to an oral disclosure, use, exhibition or other means
"P"	document published prior to the international filing date but later than the priority date claimed
"T"	later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X"	document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y"	document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&"	document member of the same patent family

Date of the actual completion of the international search
04 January 2023 (04-01-2023)

Date of mailing of the international search report
23 January 2023 (23-01-2023)

Name and mailing address of the ISA/CA
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Facsimile No.: 819-953-2476

Authorized officer
Maria Salazar (873) 353-0489

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US20120262954A1 (DUVNJAK, R.) 18 October 2012 (18-10-2012) *whole document*	1-39
A	US20050152159A1 (ISURIN, A. et al.) 14 July 2005 (14-07-2005) *whole document*	1-39

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/IB2022/060299

Patent Document Cited in Search Report	Publication Date	Patent Family Member(s)	Publication Date
US2021305901A1	30 September 2021 (30-09-2021)	US11277069B2	15 March 2022 (15-03-2022)
		CN111327182A	23 June 2020 (23-06-2020)
		CN111327182B	05 March 2021 (05-03-2021)
US2013314951A1	28 November 2013 (28-11-2013)	US9287788B2	15 March 2016 (15-03-2016)
		CN103262403A	21 August 2013 (21-08-2013)
		CN103262403B	14 September 2016 (14-09-2016)
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		CN100590954C	17 February 2010 (17-02-2010)
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		WO2006061924A1	15 June 2006 (15-06-2006)
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		US2005151517A1	14 July 2005 (14-07-2005)
		US7057376B2	06 June 2006 (06-06-2006)
		US2005151515A1	14 July 2005 (14-07-2005)
		US7106030B2	12 September 2006 (12-09-2006)
		US2005151509A1	14 July 2005 (14-07-2005)
		US7352154B2	01 April 2008 (01-04-2008)
		US2005150634A1	14 July 2005 (14-07-2005)
		US7418995B2	02 September 2008 (02-09-2008)
		US2005151508A1	14 July 2005 (14-07-2005)
		US2005151513A1	14 July 2005 (14-07-2005)
		US2008036419A1	14 February 2008 (14-02-2008)