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(54) **Title:** POWER SUPPLY SYSTEM FOR CONVERTING AN AC VOLTAGE TO A DC VOLTAGE

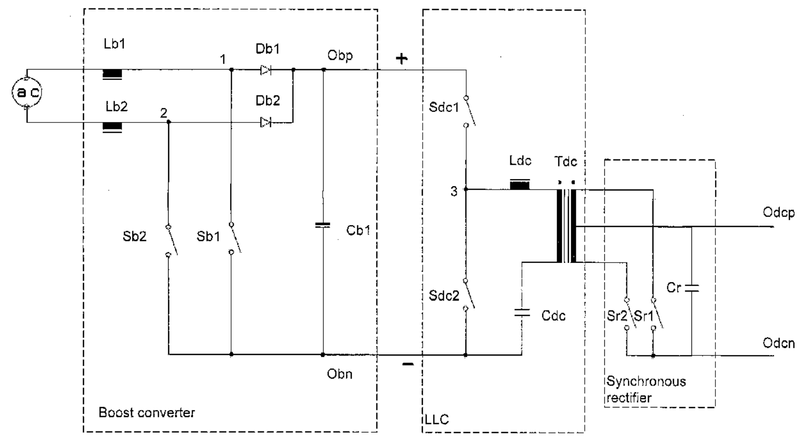

Fig. 2

(57) **Abstract:** The present invention relates to a power supply system for converting an AC voltage to a DC voltage. The system comprises a bridgeless boost converter for converting the AC voltage to an intermediate high voltage DC; a LLC resonant circuit comprising an insulation transformer device, for converting the intermediate high voltage DC into a low voltage high frequency AC; a synchronous rectifier connected to the resonant circuit, for converting the low voltage high frequency AC into the DC voltage.

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POWER SUPPLY SYSTEM FOR CONVERTING AN AC VOLTAGE TO A DC VOLTAGE

FIELD OF THE INVENTION

The present invention relates to a power supply system for converting an AC voltage to a DC voltage. The invention especially relates to a switched mode power supply (SMPS) system comprising a boost converter and a DC/DC converter.

PRIOR ART

Several types of converters are known for use in power supply systems, where there is a need to convert an AC power to a controlled DC power. The AC power will usually be supplied from an AC power source, such as the mains. The DC power is supplied to equipment such as telecommunication equipment (GSM/UMTS base stations etc), military equipment, medical equipment etc.

A telecom single phase power supply is designed to convert the utility lines AC voltage to a DC voltage which is supplied to the electronic equipment and also to charge batteries that are used for back-up power in the case of the incoming AC-voltage is disrupted. Modern telecom power supplies are usually Switched Mode Power Supplies (SMPS). A state of the art SMPS is characterized by a series of functional blocks that together fulfil the AC-to-DC conversion.

1. Input voltage rectification is implemented by using rectifying diodes in a diode bridge configuration to create an intermediate high voltage DC voltage.
2. An input filter and/or an arrangement to stabilise the intermediate high voltage DC voltage and also to shape the input current so that a unity power factor is created.
3. An arrangement for converting the intermediate high voltage DC voltage to a high voltage, high frequency AC-voltage, which is connected to the primary winding(s) of an isolation transformer.
4. Output voltage rectification by using output diodes for rectifying the high frequency, low voltage that appears on the secondary winding(s) of the isolation transformer.
5. Output voltage control and filter for stabilizing the output voltage(s).

The filters and/or arrangements for stabilising and shaping currents and/or voltages are performed by passive and/or active components. Active components, such as switches, are controlled by a control system based on measurements of relevant parameters, as is known for a man skilled in the art.

The efficiency for a state of the art SMPS for -48V DC is around 90-92%. The efficiency is usually defined as the output power measured in percentage of the total power at the at the power supplies′ input terminals where the input AC voltage is applied. Thus 8-10% of the total input power is dissipated as heat inside the SMPS.

It is known that the resistive losses caused by current conduction losses in such SMPS's are reduced by reducing the RMS-current in the DC/DC converter by the use of an LLC-series resonant circuit as described in the paper "1 MHz High Efficiency LLC Resonant Converters with synchronous Rectifier, by Dianbo Fu, Bing Lu and Fred C. Lee, Virginia Polytechnical Institute and State University, Blacksburg, USA, published on June 17, 2007." Here it is described a typical power supply for servers and telecom with a rectifier diode bridge at the input, the PFC circuit generating a 400V DC and a DC/DC converter for generating the 48V or 12 output voltage. A corresponding circuit is illustrated schematically in fig. 1A.

The object of the invention is to provide a power supply system with increased power efficiency, i.e to reduce the total energy consumption in the system by reducing the power dissipated as heat. Consequently, the need for active cooling in the form of forced air cooling by fans and the use of air conditioning units are reduced.

SUMMARY OF THE INVENTION

The present invention relates to a Power supply system for converting an AC voltage to a DC voltage, characterised in that it comprises:

a bridgeless boost converter for converting the AC voltage to an intermediate high voltage DC;

a LLC resonant circuit comprising an insulation transformer device, for converting the intermediate high voltage DC into a low voltage high frequency AC;

a synchronous rectifier connected to the resonant circuit, for converting the low voltage high frequency AC into the DC voltage.

In one aspect of the invention, the synchronous rectifier comprises MOSFET switches.

In another aspect, the synchronous rectifier comprises switches with intrinsic diodes or switches connected in parallel with anti-parallel diodes.

In another aspect, the resonant circuit comprises a set of dc-dc switches for converting the intermediate high voltage DC to a high voltage high frequency AC and that the insulation transformer device is provided for converting the high voltage high frequency AC to the low voltage high frequency AC.

In another aspect, the boost converter comprises stabilization diodes connected between a negative boost output terminal and AC input terminals of the boost converter.

In another aspect, the boost converter comprises: a first boost inductor having a first end connected to a first AC input terminal and a second end connected to a first node between the anode of a first boost diode and a first terminal of a first boost switch; a second boost inductor having a first end connected to a second AC input terminal and a second end connected to a second node between the anode of a second boost diode and a first terminal of a second boost switch; a positive boost output terminal connected to the cathodes of the first boost diode and the second boost diode; a negative boost output terminal connected to a second terminal of the first boost switch and a second terminal of the second boost switch; a boost capacitor connected between the positive boost output terminal and the negative boost output terminal.

In another aspect, the resonant circuit comprises: a first dc-dc switch connected between the positive output terminal of the boost converter and a third node; a second dc-dc switch connected between the negative output terminal of the boost converter and the third node; a dc-dc inductor connected between the third node and a first input terminal of the transformer device; a dc-dc capacitor connected between the negative output terminal of the boost converter and a second input terminal of the transformer device.

In another aspect, the synchronous rectifier comprises: a first rectifier switch connected between a first output terminal of the transformer device and an negative dc-dc output terminal; a second rectifier switch connected between a second output terminal of the transformer device and the negative dc-dc output terminal; a rectifier capacitor connected between a third output terminal of the transformer device and the negative dc-dc output terminal; where the third output terminal of the transformer device is connected to a positive dc-dc output terminal.

The power supply system comprises a control system for controlling the switches of the power supply system.

In another aspect, the positive and negative dc-dc output terminals are connected to a load.

In another aspect, the third output terminal of the transformer device is connected between the first and second output terminals of the transformer device.

In another aspect, the switches are MOSFET switches.

In another aspect, the boost converter is a two-quadrant bridgeless boost converter.

In another aspect, the boost converter is a three level boost converter.

In another aspect, the boost converter is adapted for a single phased or three phased AC input.

DETAILED DESCRIPTION

Embodiments of the invention will now be described with reference to the enclosed drawings, where:

Fig. 1A illustrates schematically a prior art power supply system;

Fig. 1B illustrates schematically a power supply system according to the present invention;

Fig. 2 illustrates details of a first embodiment of the present invention;

Fig. 3 illustrates details of a second embodiment of the present invention;

Fig. 4a-d illustrates illustrate different switching steps of the boost converter;

Fig. 5 shows measurements of some important voltages and currents of the LLC;

Fig. 6 shows measurements of the power efficiency of the present invention compared to a prior art power supply system;

Figs. 7A-D illustrate alternative embodiments of the DC-DC converter in fig. 2 and fig. 3;

Figs. 8A-C illustrate alternative embodiments of the boost converter in fig. 2 and fig. 3.

General introduction

It is now referred to fig. 1B illustrating an embodiment of the present invention schematically. The embodiment of the power supply system comprises a bridgeless boost converter connected to the AC input. The bridgeless boost converter is then connected to a resonant circuit or a so-called LLC circuit (inductor-inductor-capacitor resonant circuit) comprising an insulation transformer device (Tdc). The resonant circuit is then connected to a synchronous rectifier where the synchronous rectifier is connected to the DC output.

The bridgeless boost converter is converting the AC input voltage to an intermediate high voltage DC. The bridgeless boost converter can for example be two quadrant boost converter which is able to convert both a negative and positive input voltage to a regulated DC voltage. The boost converter can be adapted to be connected to a single phased AC input voltage or a three phased AC input voltage. The boost converter can also be a three level boost converter.

The resonant circuit is converting the intermediate high voltage DC into a low voltage high frequency AC. the resonant circuit comprises a set of dc-dc switches, which in a first step converts the intermediate high voltage DC to a high voltage high frequency AC. In a second step, the high voltage high frequency AC is converted to the low voltage high frequency AC by means of the insulation transformer device.

The synchronous rectifier converts the low voltage high frequency AC from the secondary side of the transformer device into the output DC voltage of the power supply system.

The synchronous rectifier comprises switches of MOSFET type, with integrated anti-parallel diodes. Alternatively, other types of switches can be used. In such cases, anti-parallel diodes can be connected in parallel with the switches.

The boost converter can comprise stabilization diodes connected between a negative boost output terminal and AC input terminals of the boost converter.

The present embodiment of the invention will now be described in further detail with reference to the first embodiment below.

<u>First embodiment of the invention</u>

It is now referred to fig. 2. The power supply system comprises the same elements as described above.

The bridgeless boost converter comprises a first boost inductor Lb1 having a first end connected to a first AC input terminal and a second end connected to a first node 1 between the anode of a first boost diode Db1 and a first terminal of a first boost switch Sb1.

The boost converter further comprises a second boost inductor Lb2 having a first end connected to a second AC input terminal and a second end connected to a second node 2 between the anode of a second boost diode Db2 and a first terminal of a second boost switch Sb2.

A positive boost output terminal Obp is connected to the cathodes of the first boost diode Db1 and the second boost diode Db2 and a negative boost output terminal Obn is connected to a second terminal of the first boost switch Sb1 and a second terminal of the second boost switch Sb2.

A boost capacitor Cb1 is connected between the positive boost output terminal Obp and the negative boost output terminal Obn.

The resonant circuit or LLC circuit together with the synchronous rectifier can be regarded as a dc-dc converter. Hence, the term dc-dc is used to denote some of the components below.

The resonant circuit comprises a first dc-dc switch Sdc1 connected between the positive output terminal Obp of the boost converter and a third node 3.

The resonant circuit further comprises a second dc-dc switch Sdc2 connected between the negative output terminal Obn of the boost converter and the third node 3.

A dc-dc inductor Ldc is connected between the third node 3 and a first input terminal of the transformer device Tdc.

A dc-dc capacitor Cdc is connected between the negative output terminal Obn of the boost converter and a second input terminal of the transformer device Tdc.

The synchronous rectifier comprises a first rectifier switch Sr1 connected between a first output terminal of the transformer device Tdc and an negative dc-dc output terminal Odcn.

Further, the synchronous rectifier comprises a second rectifier switch Sr2 connected between a second output terminal of the transformer device Tdc and the negative dc-dc output terminal Odcn.

A rectifier capacitor Cr is connected between a third output terminal of the transformer device Tdc and the negative dc-dc output terminal Odcn.

The third output terminal of the transformer device Tdc is connected to a positive dc-dc output terminal Odcp. In this embodiment, the third output terminal of the transformer device Tdc is connected between the first and second output terminals of the transformer device Tdc.

In operation, the DC output voltage between the positive and negative dc-dc output terminals Odcp, Odcn is connected to a load, such as a telecom base station, servers etc.

In the first embodiment, the switches are MOSFET switches with intrinsic diodes. Alternatively, other types of switches can be used, and external diodes added if they are not incorporated in the switch. The switches are, as mentioned in the introduction, controlled by a control system based on parameters such as measured voltages and/or currents. The method used by the control system for controlling the switches is known for a man skilled in the art, as mentioned in the introduction. The control system can be implemented by means of one or several analogue control circuits or digital signal processors.

Second embodiment of the invention

It is now referred to fig. 3. The power supply system comprises the same elements as described above with reference to the first embodiment, and the same names and references are used.

The second embodiment further comprises a stabilization system. The stabilization system comprises a first stabilization diode Dstab1 connected between the negative boost output terminal Obp and the first AC input terminal and a second stabilization diode Dstab2 connected between the negative boost output terminal Obp and the second AC input terminal of the boost converter.

During the development of the present invention, there was especially focus on the following mechanisms that was contributing to the heat dissipation and lowering the efficiency in the state of the art power supply systems:

1. Conduction losses caused by the forward voltage drop, V_f, in diode PN-junctions according to $P_{loss} = V_f I$
2. Resistive switching losses caused by the charge-and-discharge of parasitic capacitances in the active switching elements such as the drain-source capacitance, C_{DS}, in MOSFETs according to $P_{loss} = f_S C_{DS} V^2$
3. Resistive losses caused by current conduction losses according to $P_{loss} = RI^2$.

All of theses losses were considered in order to get a significant system loss reduction and efficiency improvement.

The conduction losses caused by the forward voltage drop in diodes are eliminated at the input by using the two-quadrant boost converter which are able to convert the

AC to DC voltage without the need for any special rectifying diodes in a diode bridge configuration. In addition the forward voltage drop is drastically reduced by replacing the rectifying diodes at the output of the SMPS by low ohmic MOSFETs. The comparison of a conventional and the two-quadrant boost converter is shown in the figures 4a-d.

The conduction losses caused by resistive switching losses are reduces and eliminated by the use of a resonant circuit in the DC-to-DC conversion stage for converting the high voltage intermediate DC voltage to a high voltage, high frequency AC-voltage connected to the primary winding of an isolation transformer. The resonant circuit has the ability to drastically reduce the switching losses by charging and discharging the parasitic capacitors in the active switching elements by the use of resonant inductors instead of discharge and charge through resistances with the corresponding resistive losses.

The resistive losses caused by current conduction losses are reduced by reducing the RMS-current in the DC/DC converter by the use of an LLC-series resonant circuit as described in the introduction.

The switching losses are drastically reduced by switching at a switching frequency Fsw corresponding to the resonant frequency Fres, given by the radio Fres = 1/sqrt(Ldc*Cdc).

A prototype according to the second embodiment of the invention has been tested and compared with a state of the art power supply system called FlatPack2 (FP2) (http://www.eltekenergy.com/wip4/detail_product.epl?cat=9835) produced and sold by Eltek Energy AS.

The power efficiency curves for the present invention and the FlatPack2 respectively are shown in fig. 6. As shown, the power efficiency in the "normal" operating range (ca 500 – 1500 W) is about 95-96% for the present invention while the power efficiency is about 90-92% for the FlatPack2. Consequently, the total losses are reduced by approximately 50%.

Alternative embodiments of the invention

Alternative embodiments of the resonant circuit or LLC are shown in fig. 7B – 7C (Fig. 7A corresponds to the LLC of fig. 2 for comparison). It should be noted that the inductor connected in parallel with the primary winding of the transformer in figs. 7A-C is a part of the transformer, in these drawings the ideal/equivalent transformer model is used. However, this built-in inductor is not shown in fig. 2, 3 and 7D. However, in yet an alternative embodiment of the invention, it would be possible to provide the LLC of these embodiments with an additional inductor connected in parallel to the primary winding.

In Fig. 7B an additional capacitor is connected between the second input terminal of the transformer device and the positive output terminal of the boost converter.

In fig. 7C the resonant circuit comprises four dc-dc switches. A first input capacitor is connected between a positive LLC input terminal (corresponding to the positive boost output terminal of fig. 2 and 3) and a middle input terminal. A second input capacitor is connected between the middle input terminal and a negative LLC input terminal (corresponding to the negative boost output terminal of fig. 2 and 3).

A first dc-dc switch is connected between the positive LLC input terminal and a first node, a second dc-dc switch is connected between the first node and the first input terminal of the transformer device, a third dc-dc switch is connected between the first input terminal of the transformer device and a second node, and a fourth dc-dc switch is connected between the second node and the negative LLC input terminal.

An inductor and a capacitor are connected in series between the middle input terminal and the second input terminal of the transformer device. A first dc-dc diode is connected between the middle input terminal and the first node and a second dc-dc diode is connected between the middle input terminal and the second node.

The secondary side of the transformer is equal to fig. 7A.

Fig. 7D shows an alternative embodiment having a voltage doubling function achieved by the configuration on the secondary side of the transformer. Here, a first switch and diode in parallel is connected between the first dc-dc output terminal of the transformer and the positive output terminal, and a second switch and diode in parallel is connected between the second output terminal of the transformer and the negative dc-dc output terminal. A first capacitor is connected between the positive dc-dc output terminal and the middle terminal of the transformer and a second capacitor is connected between the middle terminal of the transformer and the negative dc-dc output terminal.

In this embodiment, the dc-dc inductor and the dc-dc capacitor is connected in series between node 3 (shown in fig. 2 and 3) and the first input terminal of the transformer, while the second input terminal of the transformer is connected to the negative boost output terminal (i.e. the negative dc-dc input terminal).

Alternative embodiments of the bridgeless boost converter are shown in fig. 8B and 8C (Fig. 8A corresponds to the boost converter of fig. 2 for comparison).

In fig. 8B the boost converter is a three-level bridgeless boost. The boost converter comprises one boost inductor connected between the first AC input terminal and a first node. A boost diode is connected between the first node and the positive boost output terminal. A first output boost capacitor is connected between the positive boost output terminal and a middle boost output terminal (marked as “ground”). A second output boost capacitor is connected between the middle boost output terminal and a negative boost output terminal. The middle boost output terminal is connected to the second AC input terminal. A second boost diode is connected between the negative boost output terminal and the first node. Moreover, a boost switch is connected between the middle boost output terminal and the first node.

Fig. 8c shows a boost convert for connection to a three phase AC input. A first boost inductor is connected between a first AC input terminal and a first node, a second boost inductor is connected between a second AC input terminal and a second node and a third boost inductor is connected between a third AC input terminal and a third node.

A first boost diode is connected between the first node and a positive output terminal, a second boost diode is connected between the second node and the positive output terminal and a third boost diode is connected between the third node and the positive output terminal.

A fourth boost diode is connected between a negative output terminal and the first node, a fifth boost diode is connected between the negative output terminal and the second node, and a sixth boost diode is connected between the negative output terminal and the third node. A first output capacitor is connected between the positive output terminal and a middle output terminal, and a second output capacitor is connected between the middle output terminal and the negative output terminal.

A first boost switch is connected between the first node and the middle output terminal, a second boost switch is connected between the second node and the middle output terminal and a third boost switch is connected between the third node and the middle output terminal

Further modifications and variations will be obvious for a skilled man when reading the description above. The scope of the invention will appear from the following claims and their equivalents.

CLAIMS

1. Power supply system for converting an AC voltage to a DC voltage, characterised in that it comprises:

a bridgeless boost converter for converting the AC voltage to an intermediate high voltage DC;

a LLC resonant circuit comprising an insulation transformer device (Tdc), for converting the intermediate high voltage DC into a low voltage high frequency AC;

a synchronous rectifier connected to the resonant circuit, for converting the low voltage high frequency AC into the DC voltage.

2. Power supply system according to claim 1, characterized in that the synchronous rectifier comprises MOSFET switches.

3. Power supply system according to claim 1, characterized in that the synchronous rectifier comprises switches with intrinsic diodes or switches connected in parallel with anti-parallel diodes.

4. Power supply system according to claim 1, characterized in that the resonant circuit comprises a set of dc-dc switches (Sdc1, Sdc2) for converting the intermediate high voltage DC to a high voltage high frequency AC and that the insulation transformer device is provided for converting the high voltage high frequency AC to the low voltage high frequency AC.

5. Power supply system according to claim 1, characterized in that the boost converter comprises stabilization diodes (Dstab1, Dstab2) connected between a negative boost output terminal (Obp) and AC input terminals of the boost converter.

6. Power supply system according to claim 1, characterized in that the boost converter comprises:

a first boost inductor (Lb1) having a first end connected to a first AC input terminal and a second end connected to a first node (1) between the anode of a first boost diode (Db1) and a first terminal of a first boost switch (Sb1);

a second boost inductor (Lb2) having a first end connected to a second AC input terminal and a second end connected to a second node (2) between the anode of a second boost diode (Db2) and a first terminal of a second boost switch (Sb2);

a positive boost output terminal (Obp) connected to the cathodes of the first boost diode (Db1) and the second boost diode (Db2);

a negative boost output terminal (Obn) connected to a second terminal of the first boost switch (Sb1) and a second terminal of the second boost switch (Sb2);

a boost capacitor (Cb1) connected between the positive boost output terminal (Obp) and the negative boost output terminal (Obn).

7. Power supply system according to claim 1 or 6, characterized in that the resonant circuit comprises:

a first dc-dc switch (Sdc1) connected between the positive output terminal (Obp) of the boost converter and a third node (3);

a second dc-dc switch (Sdc2) connected between the negative output terminal (Obn) of the boost converter and the third node (3);

a dc-dc inductor (Ldc) connected between the third node (3) and a first input terminal of the transformer device (Tdc);

a dc-dc capacitor (Cdc) connected between the negative output terminal (Obn) of the boost converter and a second input terminal of the transformer device (Tdc).

8. Power supply system according to claim 1, 6 or 7, characterized in that the synchronous rectifier comprises:

a first rectifier switch (Sr1) connected between a first output terminal of the transformer device (Tdc) and an negative dc-dc output terminal (Odcn);

a second rectifier switch (Sr2) connected between a second output terminal of the transformer device (Tdc) and the negative dc-dc output terminal (Odcn);

a rectifier capacitor (Cr) connected between a third output terminal of the transformer device (Tdc) and the negative dc-dc output terminal (Odcn);

where the third output terminal of the transformer device (Tdc) is connected to a positive dc-dc output terminal (Odcp).

9. Power supply system according to any of the above claims, characterized in that it comprises a control system for controlling the switches of the power supply system.

10. Power supply system according to claim 1, characterized in that the positive and negative dc-dc output terminals (Odcp, Odcn) are connected to a load.

11. Power supply system according to claim 1, characterized in that the third output terminal of the transformer device (Tdc) is connected between the first and second output terminals of the transformer device (Tdc).

12. Power supply system according to any of the claims above, characterized in that the switches are MOSFET switches.

13. Power supply system according to any of the claims above, characterized in that the bridgeless boost converter is a two-quadrant bridgeless boost converter.

14. Power supply system according to any of the claims above, characterized in that the bridgeless boost converter is a three level boost converter.

15. Power supply system according to any of the claims above, characterized in that the bridgeless boost converter is adapted for a single phased or three phased AC input.

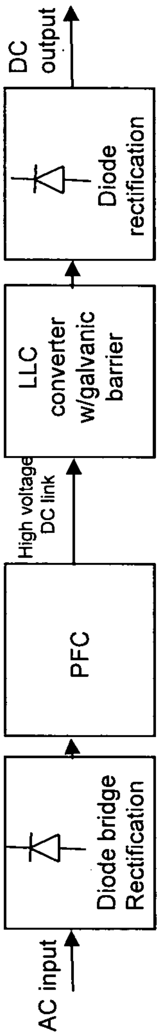

Fig. 1A: PRIOR ART

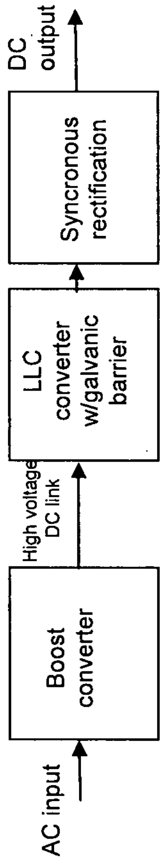

Fig1B

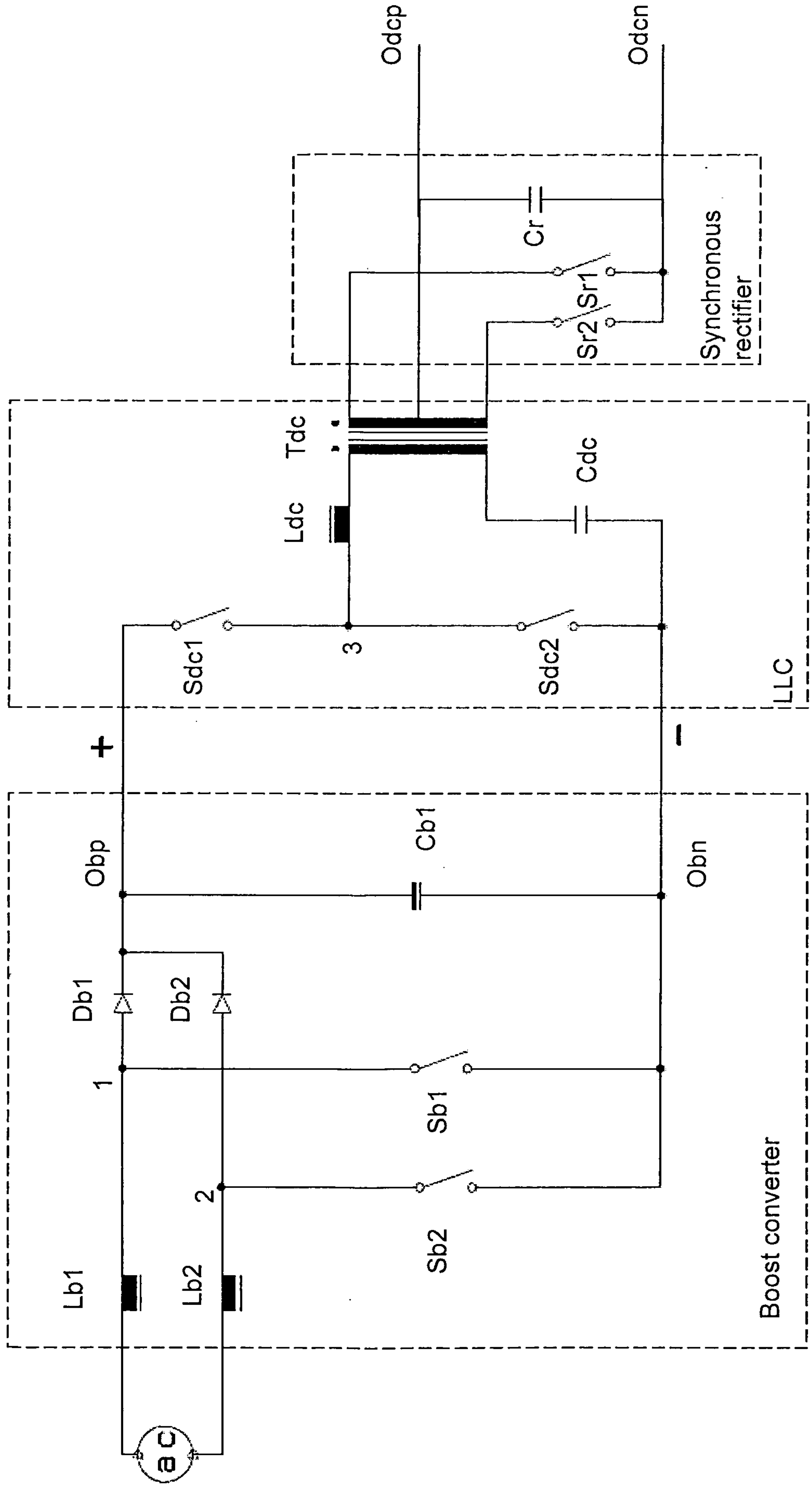
Odcp
Odcn
Cr
Sr1
Sr2
Synchronous rectifier
Tdc
Ldc
Cdc
Sdc1
3
Sdc2
LLC
+
−
Obp
Cb1
Obn
Db1
Db2
1
Sb1
2
Sb2
Lb1
Lb2
Boost converter
ac

Fig. 2

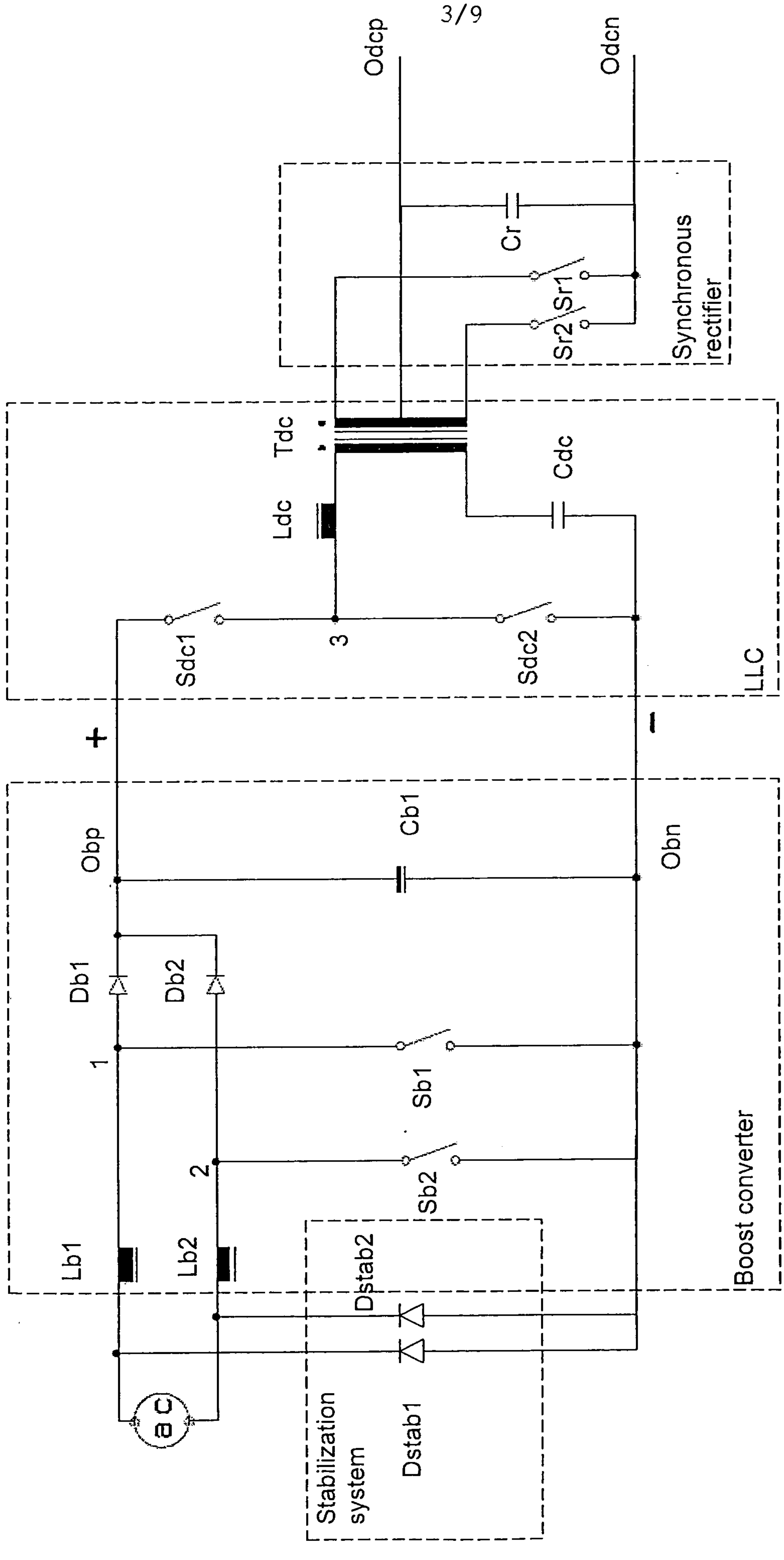
Odcp
Odcn
Cr
Sr1
Sr2
Synchronous rectifier
Tdc
Ldc
Cdc
Sdc1
3
Sdc2
LLC
+
−
Obp
Cb1
Obn
Db1
Db2
1
Sb1
2
Sb2
Boost converter
Lb1
Lb2
Dstab2
Dstab1
a c
Stabilization system

Fig. 3

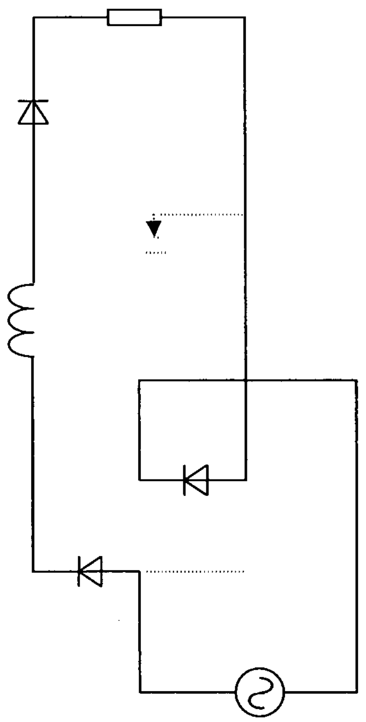

Fig 4a Conventional boost in boost inductor discharge state – 3 diode forward drops

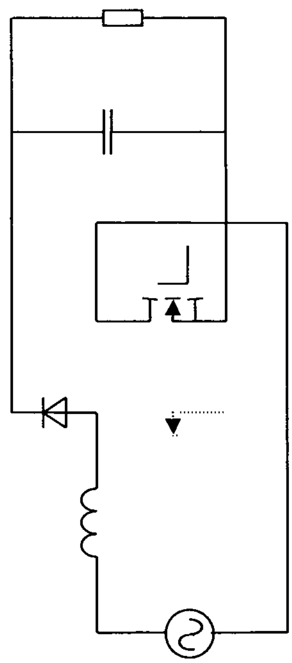

Fig 4b Two-quadrant boost in boost inductor discharge state – 1 diode and 1 MOSFET forward voltage drop

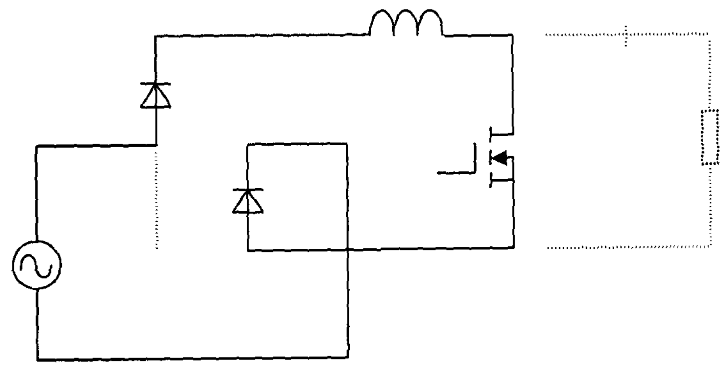

Fig 4c Conventional boost in boost inductor charge stage – 2 diode forward drops and 1 MOSFET forward drop

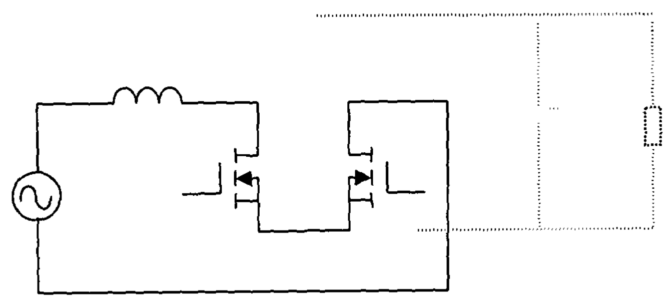

Fig 4d Two-quadrant boost in boost inductor charge stage – 2 MOSFET forward voltage drops

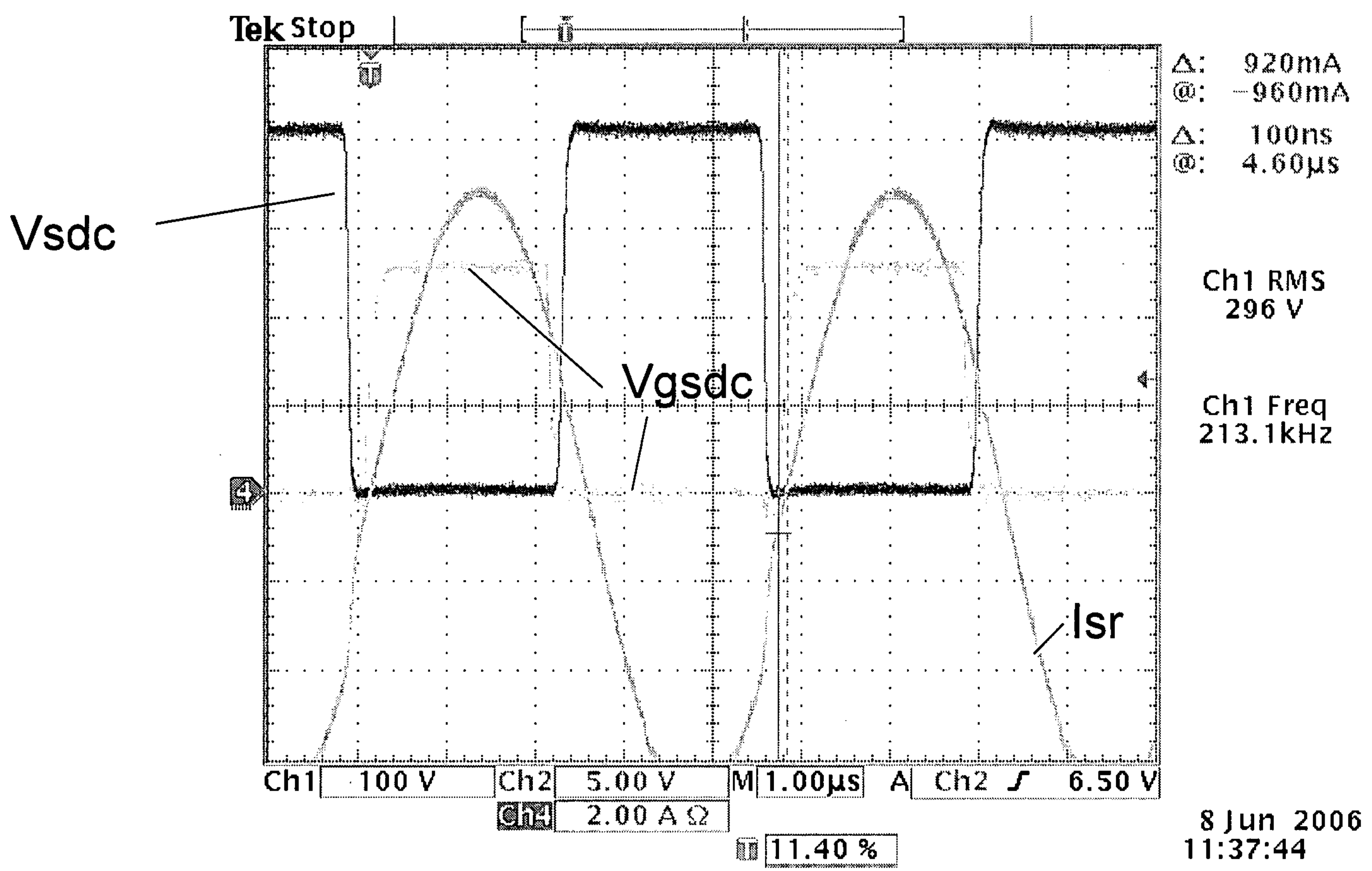

Fig. 5:
Isr: Current in resonant inductor
Vgsdc: Gate voltage on the primary side switching mosfet
Vsdc Voltage over the primary side switching mosfet

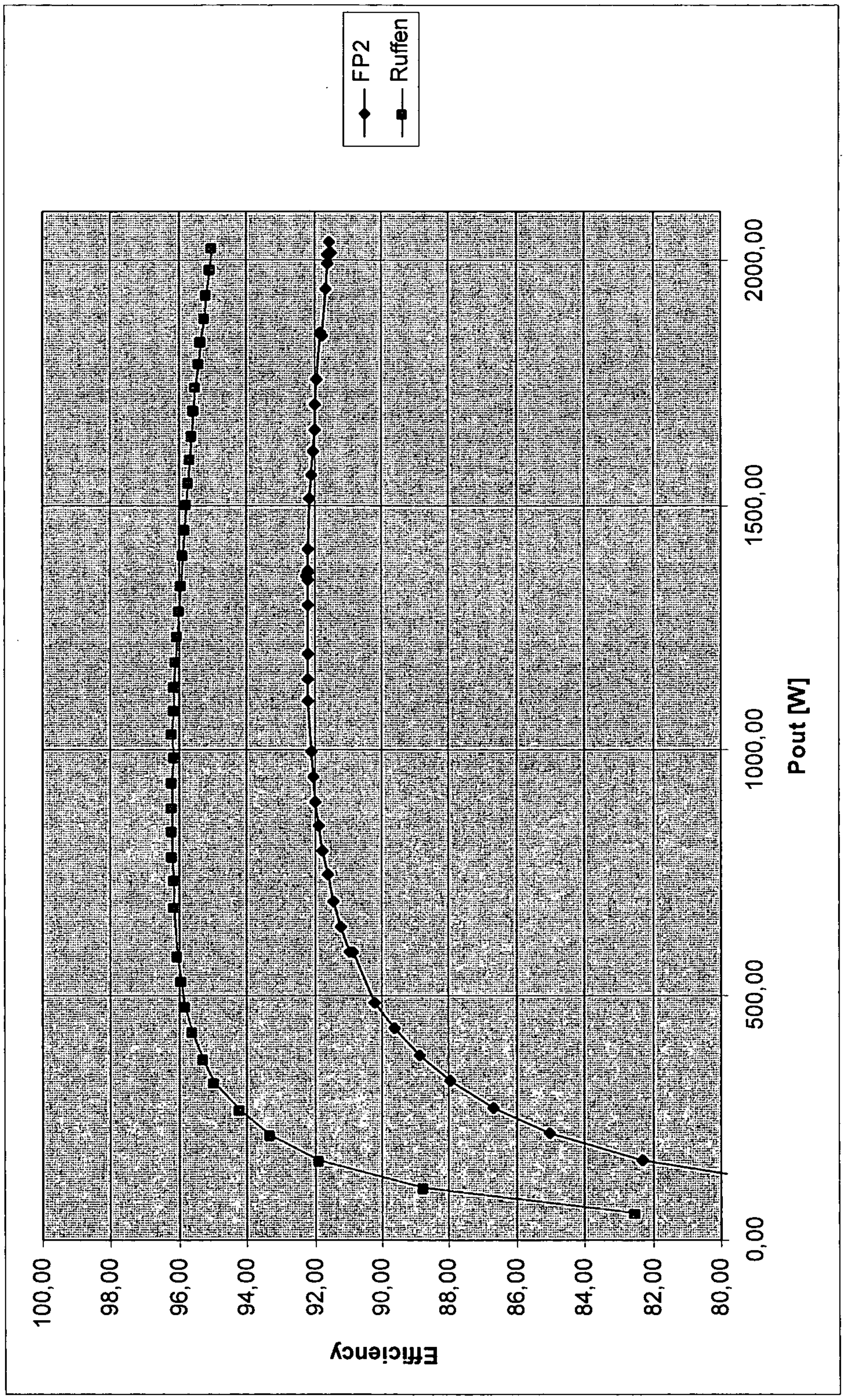
FP2
Ruffen
Efficiency
100,00
98,00
96,00
94,00
92,00
90,00
88,00
86,00
84,00
82,00
80,00
0,00
500,00
1000,00
1500,00
2000,00
Pout [W]

Fig. 6

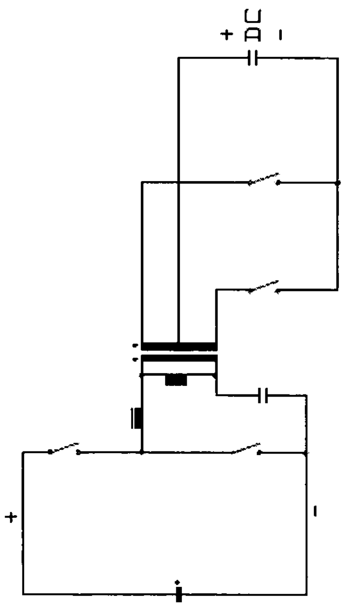

Fig. 7A

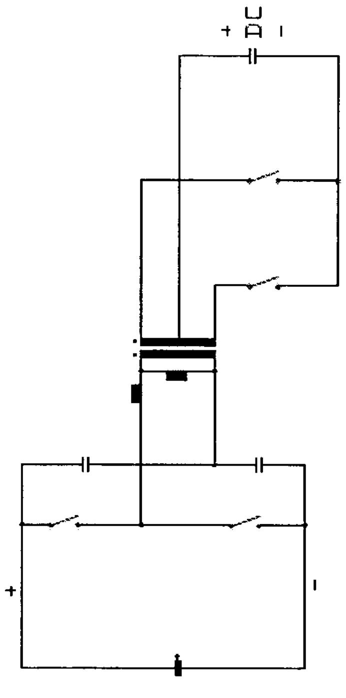

Fig. 7B

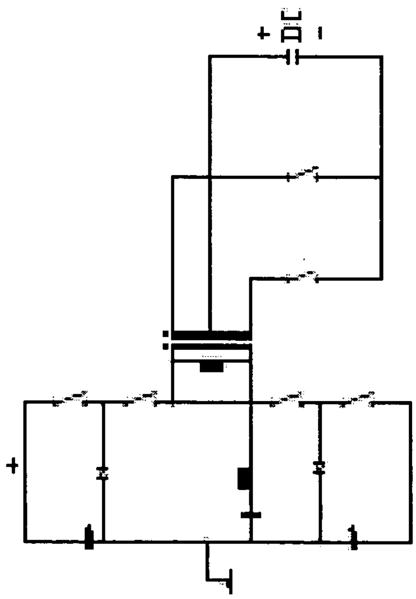

Fig. 7C

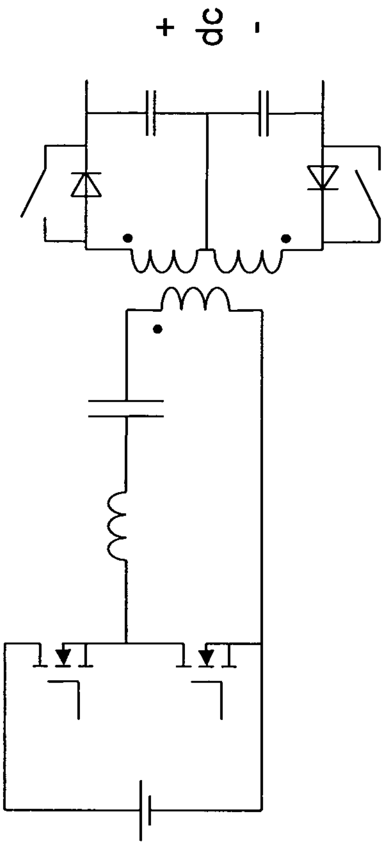

Fig. 7D

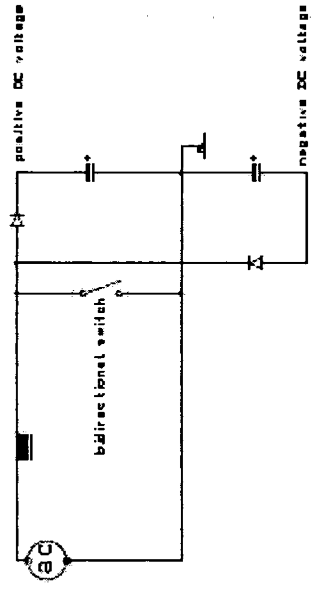

Fig. 8B

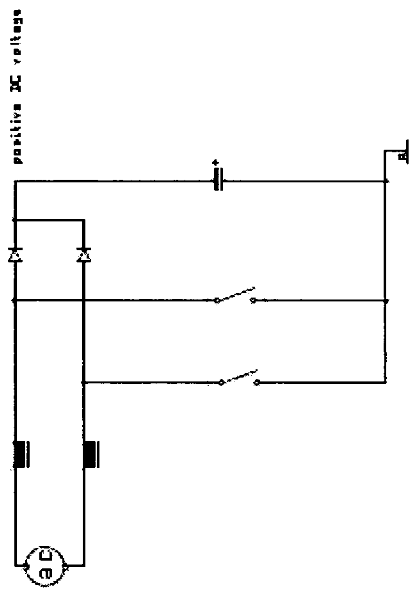

Fig. 8A

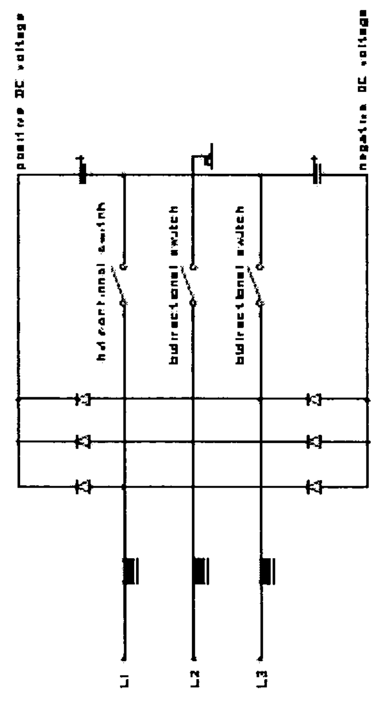

Fig. 8C

INTERNATIONAL SEARCH REPORT

International application No
PCT/NO2008/000303

A. CLASSIFICATION OF SUBJECT MATTER
INV. H02M3/335 H02M1/42

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)
H02M H03M G05F

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

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

EPO-Internal, WPI Data, INSPEC, COMPENDEX

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	DIANBO FU ET AL: "1MHz High Efficiency LLC Resonant Converters with Synchronous Rectifier" POWER ELECTRONICS SPECIALISTS CONFERENCE, 2007. PESC 2007. IEEE, IEEE, PISCATAWAY, NJ, USA, 1 June 2007 (2007-06-01), pages 2404-2410, XP031142127 ISBN: 978-1-4244-0654-8 cited in the application page 2404 - page 2405; figures 1,3,4	1-15
Y	US 2006/208711 A1 (SOLDANO MARCO [US] ET AL SOLDANO MARCO [US] ET AL) 21 September 2006 (2006-09-21) paragraphs [0005], [0009], [0011], [0012]; figures 5A,5B,10,11A,11B	1-14
	-/--	

[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
15 December 2008	30/12/2008

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Braccini, Roberto

INTERNATIONAL SEARCH REPORT

International application No
PCT/NO2008/000303

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	SALAET J ET AL: "D-Q modeling and control of a single-phase three-level boost rectifier with power factor correction and neutral-point voltage balancing" 33RD.ANNUAL IEEE POWER ELECTRONICS SPECIALISTS CONFERENCE. PESC 2002. CONFERENCE PROCEEDINGS. CAIRNS, QUEENSLAND, AUSTRALIA, JUNE 23 - 27, 2002; [ANNUAL POWER ELECTRONICS SPECIALISTS CONFERENCE], NEW YORK, NY : IEEE, US, vol. 2, 23 June 2002 (2002-06-23), pages 514-519, XP010747475 ISBN: 978-0-7803-7262-7 page 514; figure 1	14
Y	WO 2005/033819 A (INT RECTIFIER CORP [US]; SOLDANO MARCO [US]) 14 April 2005 (2005-04-14) abstract; figure 3	15
A	COSTEL PETREA ET AL: "Bridgeless Power Factor Correction Converter Working at High Load Variations" SIGNALS, CIRCUITS AND SYSTEMS, 2007. ISSCS 2007. INTERNATIONAL SYMPOSI UM ON, IEEE, PI, 1 July 2007 (2007-07-01), pages 1-4, XP031128686 ISBN: 978-1-4244-0968-6 the whole document	1
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Information on patent family members

International application No
PCT/NO2008/000303

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