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(54) **DEVICE FOR FEEDING ELECTRICAL ENERGY FROM AN ENERGY SOURCE**

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Related U.S. Patent Documents

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H02M 3/335 (2006.01)
H02M 7/5387 (2007.01)

(52) **U.S. Cl.**
USPC **363/98**; 363/21.02; 363/49

(58) **Field of Classification Search**
USPC 363/15, 16, 17, 21.02, 21.03, 97, 363/98, 131, 132, 49, 124; 323/906
See application file for complete search history.

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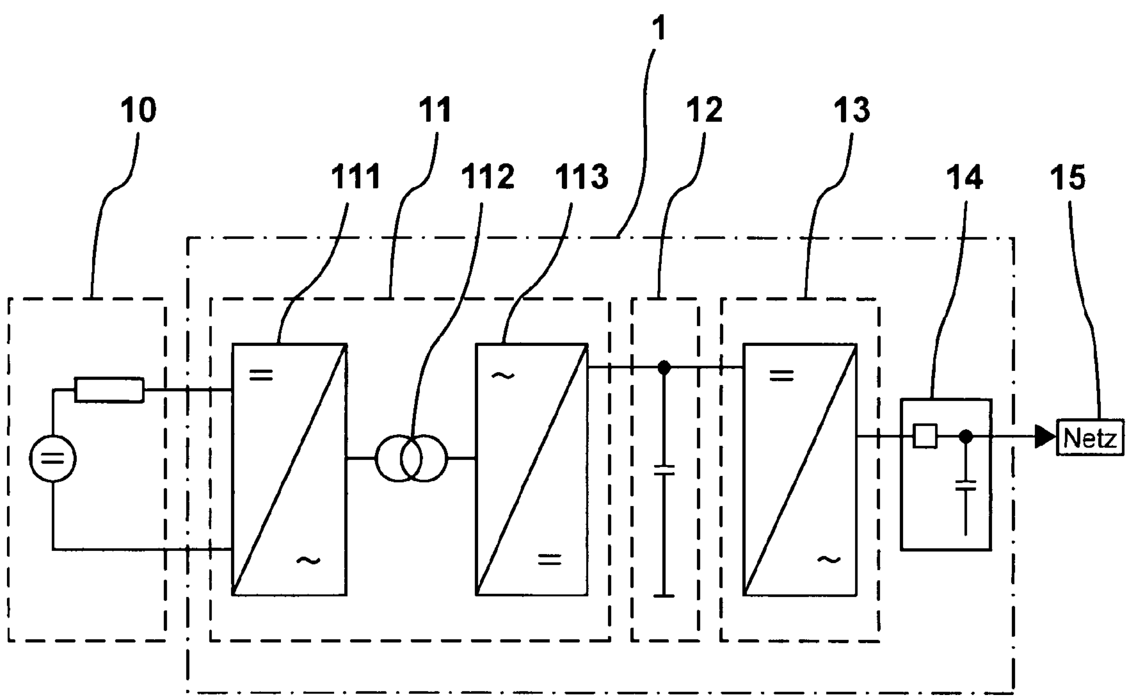
(57) **ABSTRACT**

A device (**1**) for feeding electrical energy from an energy source with variable source voltage into an electric power supply network (**15**), said device (**1**) including a transformer (**112**) for galvanic isolation, a resonant inverter (**11**) with semi-conductor switches (a-d; A, B), one or several resonant capacitors (**17**; **18**, **19**; **20**, **21**) and one rectifier (**113**), is intended to provide high efficiency and have galvanic isolation. This is achieved in that the resonant inverter (**11**) is operated in the full resonant mode if the operating voltage is in an operation point (MPP) and in the hard-switching mode if the voltages exceed the operation point (MPP).

26 Claims, 4 Drawing Sheets



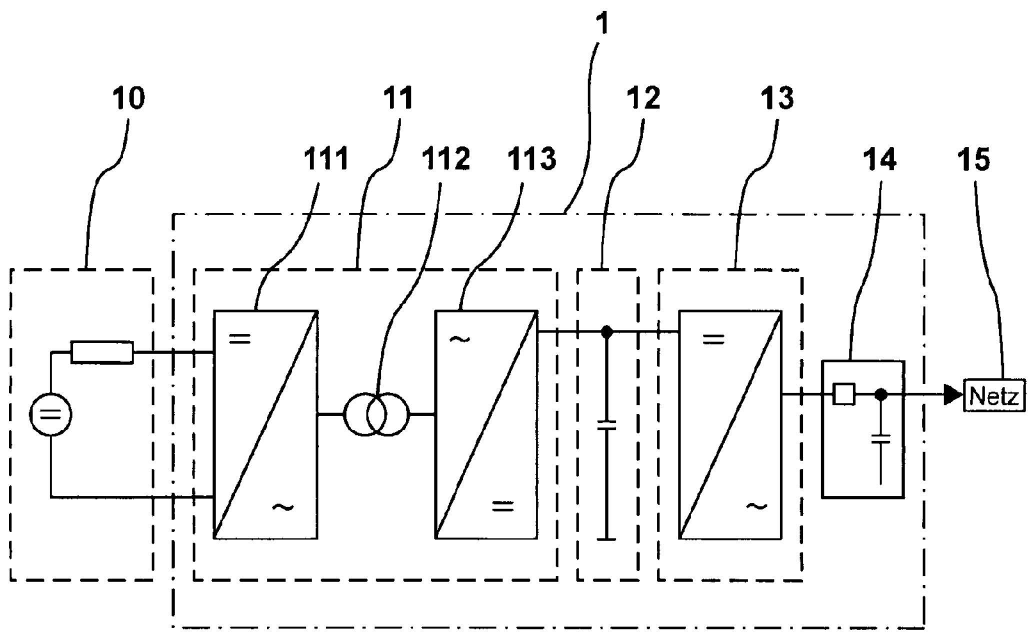


Fig. 1

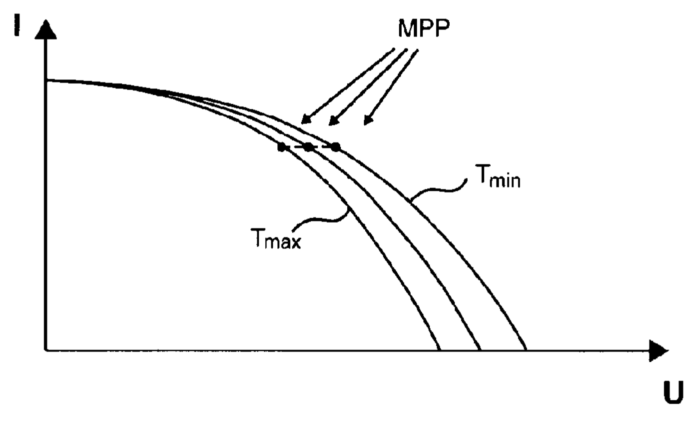


Fig. 2

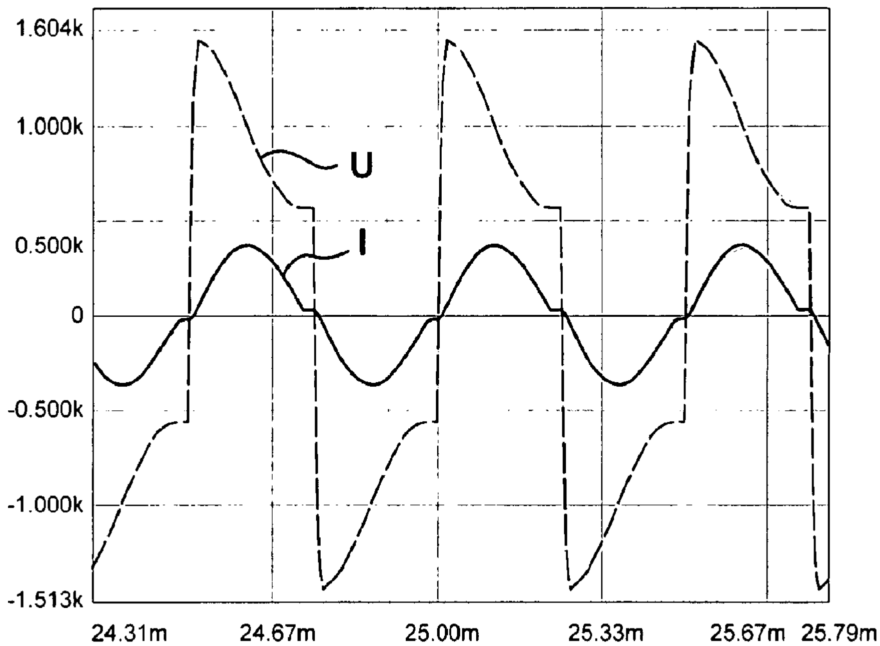

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Fig. 3

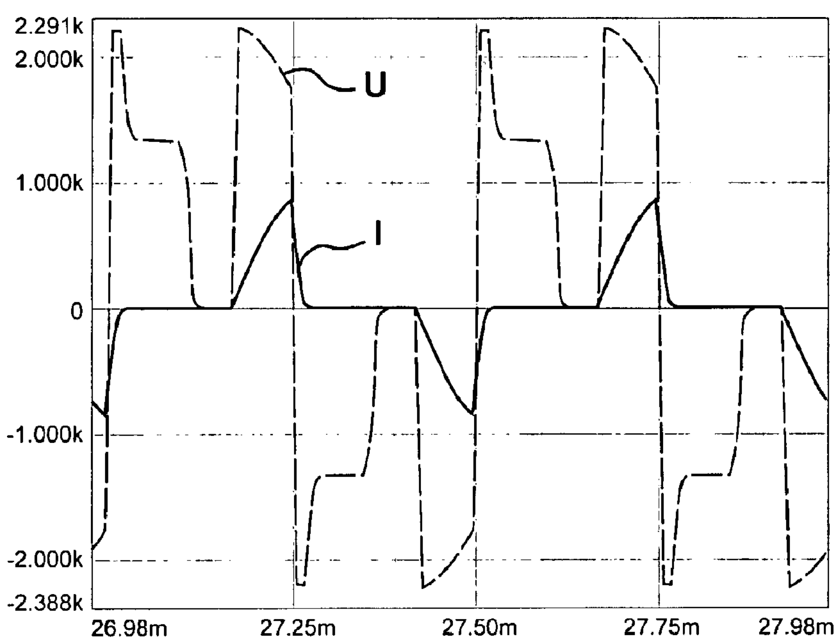
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Fig. 4

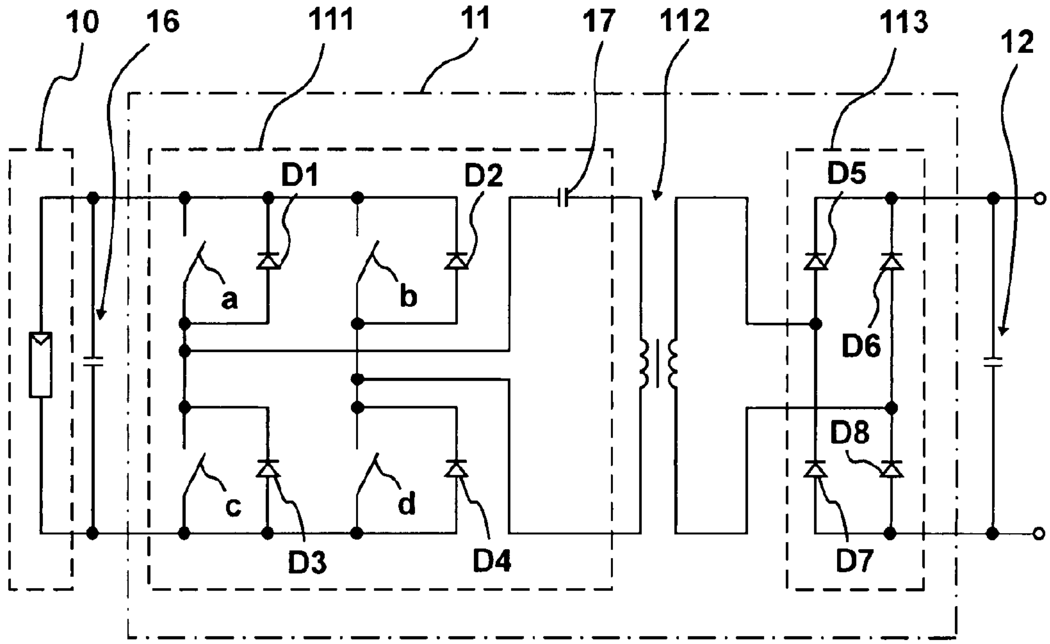
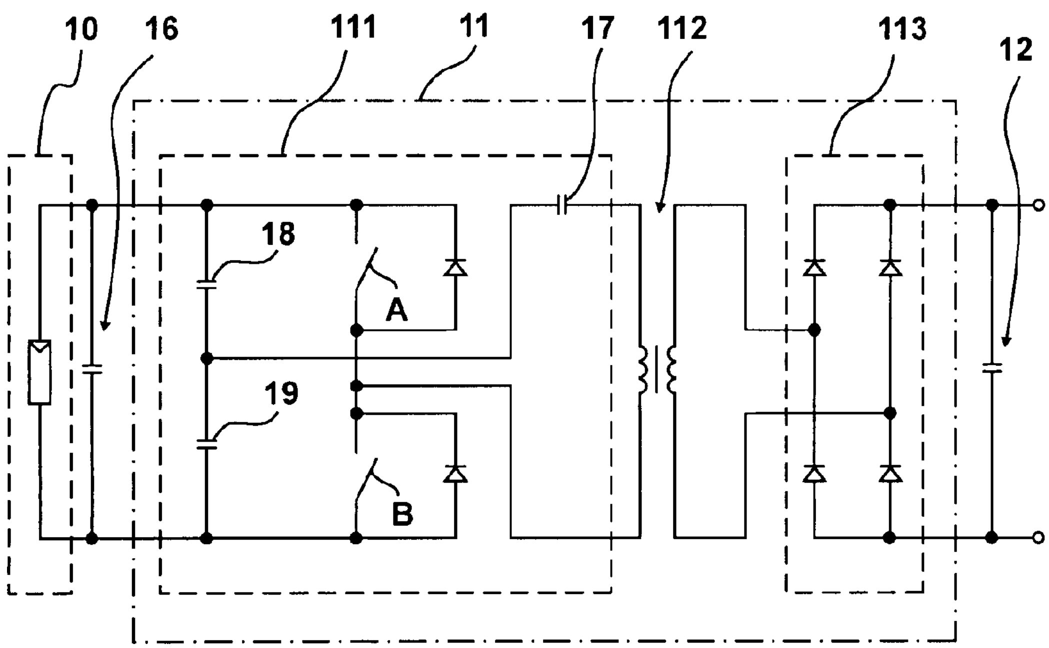

10
16
111
11
17
112
113
12
D1
D2
D5
a
b
D6
D8
c
d
D3
D4
D7

Fig. 5


10
16
111
11
17
112
113
12
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A
19
B

Fig. 6

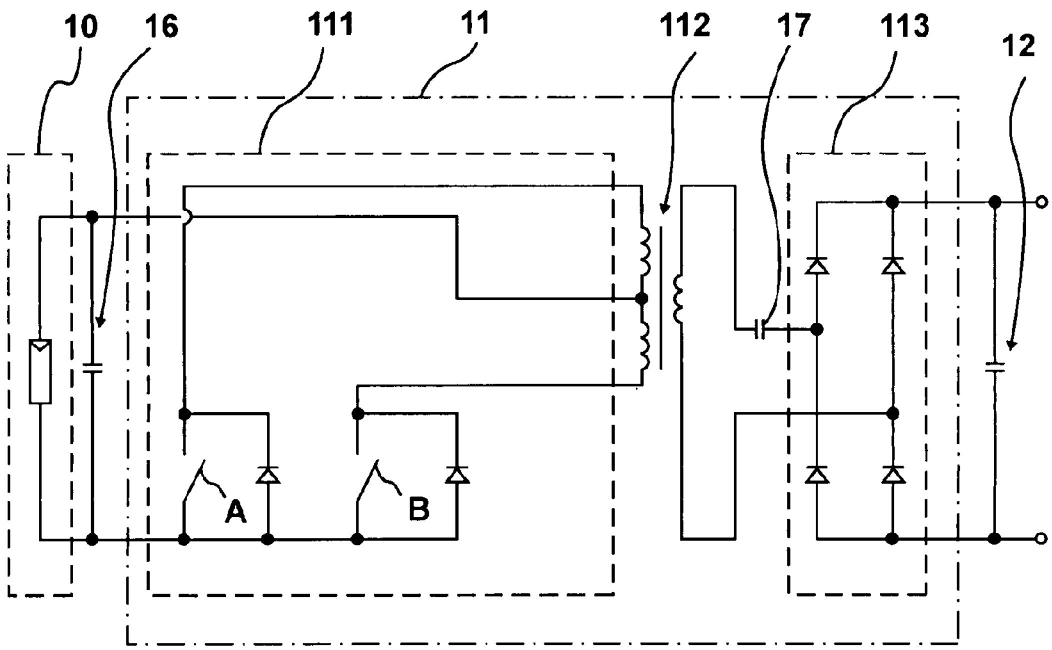

Fig. 7

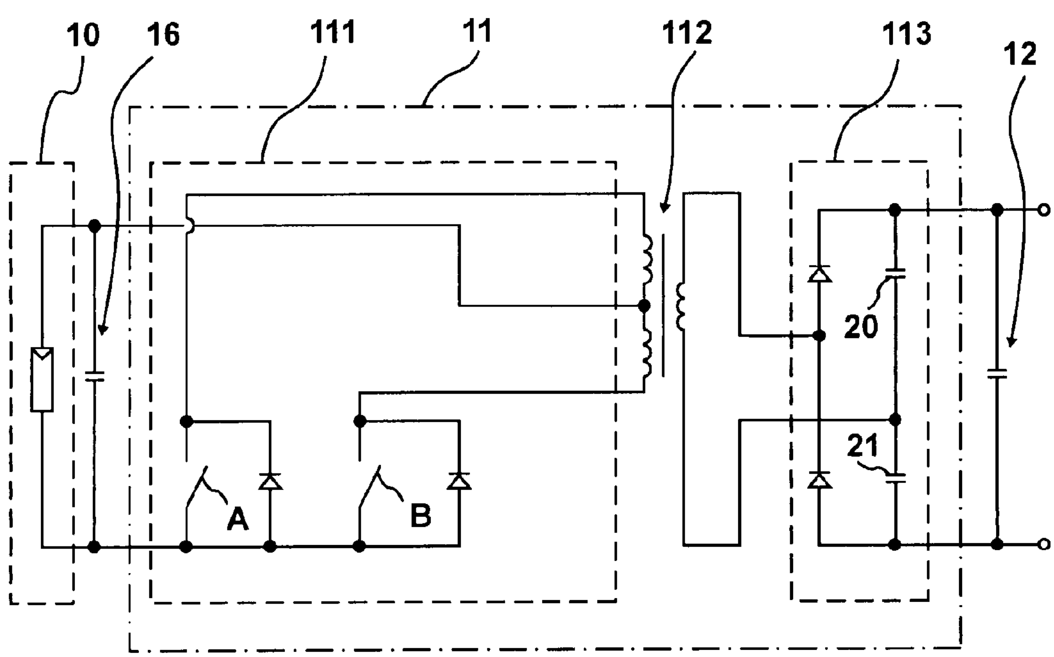

Fig. 8

DEVICE FOR FEEDING ELECTRICAL ENERGY FROM AN ENERGY SOURCE

Matter enclosed in heavy brackets [ ] appears in the original patent but forms no part of this reissue specification; matter printed in italics indicates the additions made by reissue.

CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims Priority from European Application No. EP 07002682.8 filed on Feb. 8, 2007.

FIELD OF THE INVENTION

A device for feeding electrical energy from an energy source with variable source voltage into an electric power supply network, said device including a transformer for galvanic isolation, a resonant inverter with semi-conductor switches, one or several resonant capacitors and one rectifier. Many electrical energy sources, more specifically solar generators, wind power plants with what are termed PM generators, speed-variable combustion motors, fuel cells, batteries and the like, often have a highly variable voltage and quite high an inner impedance. Usually, such energy sources are direct voltage sources but energy sources having a one-phase or a three-phase alternating voltage with variable frequency may also have a highly variable source voltage.

An adapter device is needed to feed electrical energy from such sources into a power supply device. For the electrical energy provided by a solar generator, solar inverters are known that are specially adapted to the characteristics of solar or photovoltaic cells. The energy supply device may be a public mains or an island network for one or several consumers or rather for quite a few consumers.

An adapter device of the type mentioned has several functions.

On the one side, it is intended to adapt voltage generated and frequency delivered to the conditions in the energy supply device which is to be fed. On the other side, the best possible power output is intended to be achieved for the energy source. With solar generators, optimal so-called MPP control (Maximum Operation point or power output at maximum efficiency) is to be used for obtaining the highest possible energy. Furthermore, all the safety requirements have to be observed and met when feeding in accordance with the actual standards and the valid rules of the art.

If high efficiency is achieved, the operating efficiency of the adapter device is improved and the heat loss of the plant reduced, which leads to less thermal problems. In many cases, it is necessary to galvanically isolate the energy source from the supply network because of technical requirements and of country-specific rules and standards. As a rule, an adapter device with galvanic isolation is less efficient than an adapter device without galvanic isolation.

DESCRIPTION OF THE PRIOR ART

Adapter devices with galvanic isolation are known that are implemented as one-phase or three-phase inverters having a low-frequency transformer or a high-frequency transformer.

In the first variant, an energy source with a high internal resistance is mounted downstream of a one-phase or three-phase inverter. If the energy source is a direct voltage source, a solar generator in particular, or a fuel cell, the inverter may be connected directly. In the case of alternating voltage sources, of wind or water power plants having a PM generator, a rectifier must be mounted therein between. Usually, the inverter is implemented as an H-bridge in one-phase plants or as a three-phase bridge in three-phase plants.

As a rule, a sinus filter and a transformer are mounted downstream of the inverter. The power supply device is connected to the secondary side of the transformer. Such a device has long been known.

In the variant having a low-frequency transformer, the transformer's transformation ratio must be chosen such that electrical energy may still be fed even if the voltage at the energy source is low or minimum and the mains voltage at its maximum. The minimum voltage occurs in particular with a solar generator when irradiation is at its maximum and, as a result thereof, if the current and the ambient temperature are high. As a result, the current on the primary side of the transformer may be very high. The semi-conductor switches of the low frequency inverter must be devised for this high current on the one side and on the other side also for the maximum voltage of the energy source. Due to the switching losses in the semi-conductor switches of the low-frequency inverter, the losses increase with rising voltage at the energy source.

The variant with the low-frequency transformer further suffers from other disadvantages.

The low-frequency transformer is of quite large dimensions and is very heavy. This variant works with high currents on the primary side of the transformer because the transformation ratio must be adapted to the case of the minimum voltage at the power source and of maximum voltage in the power supply network. Furthermore, the semi-conductor losses increase with rising voltage at the energy source. Another advantage is that the higher the maximum admissible off-state voltage of the semi-conductors, the higher the on-state and switching losses, this resulting in a small efficiency of the adapter device.

In the second variant having a high-frequency transformer, a high-frequency inverter (HF-inverter) is mounted downstream of an energy source with quite high an internal resistance. If the energy source is a direct voltage source, more specifically if it is a solar generator or a fuel cell, the high-frequency inverter may be connected directly. In alternating voltage sources such as wind or water power plants having a PM generator, a rectifier must be mounted therein between.

The high-frequency inverter generates a high-frequency alternating voltage the high-frequency transformer transforms to the secondary side thereof. There, the alternating voltage is rectified with a diode rectifier.

The rectifier feeds a direct voltage intermediate circuit. A low-frequency inverter (LF inverter) is mounted downstream of the direct voltage intermediate circuit in the form of an H-bridge in one-phase plants or in the form of a three-phase bridge in three-phase plants. The supply network is connected to the low-frequency inverter through a sinus filter.

Because the energy source comprises a strongly variable voltage in the cases described herein, an adapter must often be connected between the energy source and the high-frequency inverter in order to keep the direct voltage intermediate circuit stable on the secondary side. This is particularly the case if the high-frequency inverter is configured to be a resonance converter. Although resonance converters are highly efficient, they cannot be utilized for adapting the voltage.

The document EP 1 458 084 A2 explains a device with a resonant switching high-frequency inverter. A resonant DC-DC converter having a high-frequency transformer is used. An input direct voltage, which may more specifically be made available by a solar generator, is converted to alternating voltage through a full bridge and transformed by the high-frequency transformer. On the secondary side, there also is a full bridge that is implemented for the converter to be operable on both directions. An additional inductance and an additional capacitor, which are connected in series to the secondary winding of the high-frequency transformer, form a resonant circuit.

Since the output voltage of the solar generator is subjected to strong fluctuations whilst a stable voltage is to be available behind the rectifier in the direct voltage intermediate circuit, an additional adapter stage must be provided in practice. This adapter stage may be disposed before or behind the DC-DC converter. It may be implemented as a boost chopper or as a buck chopper.

Another device is known from the German Patent Application Publication DE 10 2005 023 291 A1. This device includes such an adapter device. The adapter device consists of a resonant converter with galvanic isolation and of a boost chopper mounted upstream thereof. Such an adapter stage however causes additional costs and requires additional space. Furthermore, additional losses are originated in such a stage. Accordingly, this not only makes it necessary to provide for an additional adapter stage, which involves more components, more costs and more space, but also suffers from the serious disadvantage that the efficiency is reduced by such an additional stage.

Not only devices with resonant switching high-frequency inverters are known, but also such with hard-switching high-frequency inverters.

If a high-frequency inverter is configured to be a hard-switching inverter, it may be utilized for performing the required voltage adapter but suffers from the disadvantage that it has poor efficiency.

The German Patent Application Publication DE 199 37 410A1 shows and describes a variant having a hard-switching high-frequency inverter. A direct voltage source configured to be a solar module and having a buffer capacitor is adjoined with a full bridge converting the direct voltage into alternating voltage. Through a high-frequency transformer, this alternating voltage is transformed on the secondary side. The output voltage of the transformer is rectified, an intermediate circuit capacitor mounted downstream thereof being charged. An adjoining three-phase inverter generates an approximately sinusoidal output voltage that corresponds in amplitude and frequency to the mains voltage.

The transformer's transformation ratio of the high-frequency transformer must be chosen such that electrical energy can be fed even if the voltage at the energy source is at its lowest and the mains voltage at its highest. This voltage occurs in particular in a solar generator when the irradiation is at its highest and when the ambient temperature is high. As a result, the primary side current of the high-frequency transformer is very high. The semi-conductor switches of the high-frequency inverter must be devised for these high currents. Concurrently, the semi-conductor switches must be devised for maximum voltage of the energy source. Due to the switching losses in the semi-conductor switches of the high-frequency inverter, the losses increase with rising voltage at the energy source.

The solution according to the printed document DE 199 37 410 A1 is disadvantageously characterized by high currents on the primary side of the high-frequency transformer, with the semi-conductor losses increasing with rising voltage at the energy source. It must be taken into consideration that the higher the highest admissible off-state voltage, the higher the on-state and switching losses.

The inconvenient of this solution is that there are considerable semi-conductor losses resulting from the hard-switching operation because in this operation point high switching losses are generated in the high-performance semi-conductors. This results in a small efficiency of the adapter device.

BRIEF SUMMARY OF THE INVENTION

It is the object of the invention to provide a highly efficient adapter device for feeding electrical energy from an energy source with variable source voltage into an electric power supply network, the device including a transformer for galvanic isolation, a resonant inverter with semi-conductor switches, one or several resonant capacitors and one rectifier, the resonant inverter being operated in the full resonant mode if the operating voltage is in an operation point, (MPP) and in the hard switching mode if the voltages exceed the operation point (MPP).

Further, the number of semi-conductor switches through which current flows should be the smallest possible, a resonant-switching high-frequency inverter being intended to be used without need for an additional adapter stage.

The solution to this object is achieved in that the resonance inverter is fully resonant when the operating voltage is in an operation point (MPP) and is operated so as to be hard-switching with voltages above the operation point (MPP).

The solution of the invention offers galvanic isolation between the energy source and the supply network while achieving very high efficiency at low cost. It combines the advantages of a resonant inverter with those of a hard-switching inverter, namely small switching losses, without the need for an adapter stage such as a boost chopper or a buck chopper.

For the control of the invention there is provided a control means, more specifically a microprocessor.

The invention relies on the observation that, although the losses in the resonant inverter in the hard-switching operation mode are significantly higher than in the fully resonant operation mode, this drawback can be tolerated since the operation point in a hard-switching resonant converter is very limited in time and only occurs in the start-up phase in which the energy source is not loaded. As a result, one generally obtains a very good efficiency without any additional adapter stage.

Galvanic isolation makes it possible to readily comply with standards and regulations.

Accordingly, the resonant converter utilized has a very advantageous efficiency so that the invention may totally obviate the need for an additional adapter stage by operating the resonant converter in the fully resonant operation mode in the maximum operation point, i.e., in the resonant point and by operating it in the hard-switching mode when the voltages exceed a voltage of the energy source associated with this operation point. As a result, the switching losses generally drop and the efficiency of the device is improved.

The invention has a particularly favourable impact on generators having high internal impedance. Here, efficiency can be considerably improved without adapter stage. An implementation as a solar inverter is particularly beneficial.

In an advantageous developed implementation of the invention, there is provided that, in the operation point (MPP), the semi-conductor switches of the resonant inverter are operated with a duty cycle that is more than half a period of the resonance frequency of an oscillating circuit. The oscillating circuit consists of the resonant capacitor(s) and of a transformer leakage inductance. Operation occurs at pulse widths ranging between 30 and 50% of the period of the pulse frequency so that a voltage at an intermediate circuit capacitor will not fall below a minimum value needed for feeding the network. This also applies when the operation point, more specifically the MPP voltage of the energy source, adopts a minimum value imposed by the device. Advantageously, when the voltages of the energy source are higher than the MPP voltage, the device is operated with pulse widths ranging between 0 and 50% so that the voltage at the intermediate circuit capacitor will not exceed a maximum value given by the electric strength of the semi-conductor switches of the regen-capable inverter, even if the voltage of the energy source is higher than the MPP voltage. In normal operation (MPP operation), this provision allows obtaining a current made from low-loss sinusoidal half-waves. Semi-conductor switches having quite small off-state strength may be utilized.

If semi-conductor switches of the same electric strength are used in the resonant inverter or resonant converter, which in principle is a DC/AC converter, and in the regen-capable inverter, which also is a DC/AC converter, the manufacturing costs are reduced by using components of the same type.

It is particularly advantageous if, in hard-switching operation above the operation point, a transformer current of the transformer consists of sine-wave portions. Although this causes switch-off losses to occur, it does not generate switch-on losses in the inverter.

Advantages of high-frequency inverters may be utilized if a high-frequency inverter is mounted upstream of the transformer, the high-frequency inverter being part of the resonant inverter or forming it. The high-frequency inverter comprises the semi-conductor switches for converting the direct voltage of the energy source into a high-frequency voltage. The switches are more specifically implemented as MOS transistors, IGBTs, GTOs.

In order to minimize the switching losses in the semiconductor switches of the resonant converter as compared to hard-switching operation, it is beneficial if the resonant inverter, the transformer and the inverter form a resonant converter or a unit (DC/DC unit), the natural frequency formed by one or more resonant capacitors and a leakage inductance of the transformer being higher than a switching frequency of the resonant inverter. This is to say that a high-frequency inverter, the transformer and the rectifier form a resonant converter. This switching frequency is provided in order to minimize the switching losses in the semi-conductor switches (a-d; A, B) of the resonant converter as compared to a hard-switching mode of operation.

In an advantageous implementation of the invention, a high-frequency transformer is utilized instead of a low-frequency transformer.

The inverter is very light-weighted and has small dimensions if the high-frequency inverter is provided with the high-frequency transformer and a high-frequency rectifier.

According to another preferred embodiment of the apparatus of the invention, it is intended to reduce the ripple current loads in the energy source and in the intermediate circuit capacitor. This is achieved in that several resonant inverters are connected in parallel at the energy source on the primary side and are connected to a common intermediate circuit capacitor on the secondary side, the various resonant converters being clocked at different times.

A system having a device the energy source of which is a solar generator is particularly favourable. Said generator has quite high internal impedance but also quite high no-load voltage by virtue of the typical characteristic line of the solar cell. The invention may however also be utilized to advantage if the energy source is a fuel cell, a battery, a wind power plant with permanent-magnet generator, a combustion engine with a permanent-magnet generator or a water power plant with a permanent-magnet generator (PM-generator). These sources may also have a strongly varying voltage and high internal impedance.

Since solar generators may achieve quite high no-load voltage and since they are always to be operated in the MPP, it is very advantageous if the energy source is a photovoltaic solar generator having at least one MPP of a solar generator characteristic line, the resonant inverter being operated in the fully resonant mode in the MPP and in the hard-switching mode if the voltages are higher than the MPP. The off-state voltage of the semi-conductor switches can be significantly reduced. The MPP is also variable, such as because of the temperature fluctuations in the solar generator within one day.

Other advantageous embodiments of the invention are recited in the dependent claims.

The invention and other advantages thereof will be better understood when reading the following description of the figures.

BRIEF DESCRIPTION OF THE SEVERAL VIES OF THE DRAWING

FIG. **1** shows a schematic diagram of a preferred embodiment of the invention,

FIG. **2** shows a current/voltage diagram and characteristic lines of an energy source,

FIG. **3** shows primary side current and voltage curves of a transformer of the device of the invention,

FIG. **4** shows other primary side current and voltage curves of a transformer of the device of the invention,

FIG. **5** shows a diagram of a preferred solution of the invention,

FIG. **6** shows a diagram of a first implementation variant of the preferred solution of the invention,

FIG. **7** shows a diagram of a second implementation variant of the preferred solution of the invention,

FIG. **8** shows a diagram of a third implementation variant of the preferred solution of the invention.

DETAILED DESCRIPTION OF THE INVENTION

The fundamental function of the device **1** of the invention will be first explained referring to FIG. **1**, reference being made to the FIGS. **5** through **7** as well.

The device **1** comprises a resonant converter or rather a resonant inverter **11** (DC/DC inverter) with a high-frequency inverter **111** and a high-frequency rectifier **113**, both being connected together by a high-frequency transformer **112** connected therein between in order to provide for galvanic isolation. The converter or inverter **11** virtually is (without regen-capable inverter) a DC/DC converter and serves for voltage adaptation and galvanic isolation. The transformer **112** is disposed in the resonant inverter **11**. A direct voltage output of the high-frequency rectifier **113** leads to a direct voltage intermediate circuit (intermediate circuit capacitor **12**), as can be seen from FIG. **1**. As the last stage, the device **1** has a regen-capable inverter **13** connected downstream of the direct voltage intermediate circuit (intermediate circuit capacitor **12**).

An energy source, preferably a direct voltage source, more specifically a photovoltaic or solar generator **10**, intended for delivering electrical energy to an alternating voltage network or an energy supply network **15**, is connected to an input of the device **1**. The resonant inverter **11** is connected directly downstream of the energy source. The output of the regen-capable inverter **13** is hereby connected to the mains **15**, an appropriate mains filter **14** being preferably connected downstream of the regen-capable inverter **13**.

The device **1** works as an adapter device **1** and adapts the voltage provided by the energy source or the solar generator **10** to the voltage and frequency conditions in the energy supply network **15** that has to be fed. The high-frequency inverter **111** converts the direct voltage of the solar generator into alternating voltage that is transformed through the high-frequency transformer **112** to the voltage level desired. On the secondary side of the transformer **112**, the voltage is rectified by the rectifier **113**.

The transformation ratio of the high-frequency transformer **112** ensures that, in an MPP range, i.e., at a point of the characteristic line at which the output of the generator is highest, the solar generator **10** has such a high voltage at the direct voltage intermediate circuit (intermediate circuit capacitor **12**) that feeding the energy supply network **15** is possible.

FIG. **2** shows by way of example a typical set of characteristic curves of the solar generator **10**. In the no-load state of the solar generator **10**, the voltage of the generator **10** is at its highest. In the so-called MPP, the voltage is lower than at no-load. It is in this working point however that the highest energy yield is achieved so that the solar generator **10** should be operated durably in this point. With increasing temperature, i.e., within the course of the day or during prolonged operation of the solar generator, the characteristic line is displaced because solar cells of the generator **10** are subjected to heating. At the same solar irradiation condition, solar cells yield higher no-load voltage and also higher output when the temperature is not so high. Accordingly, the no-load voltage decreases with increasing heating, which is denoted by Tmin and Tmax (T=solar cell temperature). The MPP voltage is also displaced according to FIG. **2** so that the MPP range settles between Tmin and Tmax. The resonant inverter **11** comprises a resonant capacitor **17**, as shown in FIG. **5**.

In accordance with the invention, the resonant inverter **11** is always operated in the full resonant mode in the MPP range of the solar generator **10**. FIG. **3** shows the typical curve of the transformer primary current I of the high-frequency transformer **112** as well as of its primary voltage U. While the resonant capacitor **17** is charge exchanged, an almost sinusoidal current flows through a primary winding of the transformer **112**. It is preferred that the resonance frequency is thereby determined by the leakage inductance of the transformer **112** and by the resonant capacitor **17** and is adjusted so as to be higher than the clock frequency of the semi-conductor switches a-d or A, B of the resonant inverter **111**. The resonant inverter **11** more specifically comprises two or four semi-conductor switches a, b, c, d, A, B, which are transistors in particular. The semi-conductor switches a, b, c, d, A, B of the resonant inverter **111** switch at the time when the current in the primary winding is almost zero. A switching loss minimum is thus ensured. After completion of the charge exchange process of the capacitor, a small residual current, namely the magnetization current, is still flowing. The transformer voltage is determined by superimposing the voltage at the intermediate circuit (intermediate circuit capacitor **12**) in accordance with the transformation ratio and with the voltage above the resonant capacitor **17**. The resonant capacitor **17** is charge exchanged during the sinusoidal current flow. The charge exchange process can be clearly traced in the transformer voltage (see FIG. **3**). The transistors or semi-conductor switches a, b, c, d or A, B of the resonant inverter **11** are operated in the MPP with pulse widths of approximately 30 and 50% of the period so that the voltage at the intermediate capacitor **12** will not fall below the minimum value needed for feeding the mains **15**, even if the MPP voltage of the solar generator **10** adopts the minimum imposed by the system.

The voltage in the direct voltage intermediate circuit (intermediate circuit capacitor **12**) must in particular be higher than 1.5 times the peak value of the conductor voltage in the energy supply network if the inverter **11** is a three-phase inverter or it must be higher than 1.5 times the peak value of the midpoint voltage in the energy supply network if the inverter is a one-phase inverter. If the voltage in the direct voltage intermediate circuit (intermediate circuit capacitor **12**) is higher than this minimum voltage, the fine adjustment is performed by the one-phase or three-phase inverter.

In case the solar generator **10** is not loaded, the voltage can be much higher than in the MPP range, due to its high internal impedance. If in this operation condition, which may occur for example during start-up of the feeding device **1**, the resonant inverter **11** is operated in the full resonant mode, the voltages in the direct voltage intermediate circuit (intermediate circuit capacitor **12**) may exceed the voltages for which the semi-conductor switches e.g., D**5** through D**8** and the semi-conductor switches of the mains parts **13** of the adapter device **1** are devised.

If the voltage of the solar generator **10** exceeds the MPP voltage, the resonant inverter **11** is operated in what is referred to as the hard-switching mode of operation. In this operation point, the semi-conductor switches, e.g., a-d of the resonant inverter **11** or of the high-frequency inverter **111**, hard-switch the transformer current off. One thus obtains the curves shown in FIG. **4** for the transformer primary current I and the transformer primary voltage U. If the voltages of the solar generator **10** are higher than the MPP voltage, the semi-conductor switches e.g., a-d of the inverter **11** or **111**, are preferably operated at pulse widths of between zero and 50% so that the voltage at the intermediate circuit capacitor **12** will not exceed a maximum value given by the electric strength of semi-conductors, more specifically of semi-conductor switches of the regen-capable inverter **13**, even if the voltage of the solar generator **10** is higher than the MPP voltage. The resonant inverter **11** may regulate the voltage in the direct voltage intermediate circuit (intermediate circuit capacitor **12**). The losses in the resonant inverter **11** are thereby significantly higher than in the full resonant mode of operation. This drawback however may be accepted since the operation point with a hard-switching resonant inverter **11** is very limited in time and only occurs in the starting phase in which the energy source is not loaded. If the duty cycle is more than half the period of the resonance frequency of the oscillating circuit formed from resonant capacitor and transformer leakage inductance and is generally between 30% and 50%, the current formed would be sinusoidal. For shorter switch-on times the sinusoidal current is phase-controlled and one obtains through the transformer primary winding the current shown by way of example in FIG. **4**. At the beginning of the current flow, the capacitor **17** is maximally charged. As the current increases, the capacitor **17** is charge exchanged. If the semi-conductor switches, e.g., a-d of the inverter **11** or **111**, are switched off, the current flows through the diodes, e.g., D**1**-D**4**, confronting the semi-conductor switches, e.g., a d, in the associated commuting group, until it has decayed. The transformer voltage is again determined by superimposition of the voltage at the intermediate circuit (intermediate circuit capacitor **12**) according to the transformation ratio and of the voltage at the resonant capacitor **17**. If a pair of the confronting semi-conductor switches, e.g., a-d, of the resonant inverter **11** is respectively open, the capacitor **17** is charge-exchanged. The voltage change at the capacitor **17** is accordingly mapped in the transformer voltage. In the commuting phase after the active switches, e.g., a-d, have switched off and as long as the current flows through one of the diodes D**1** through D**4**, a voltage peak is induced in accordance with the current flow of the falling flank. The voltage then drops to the level of the intermediate circuit voltage at the capacitor **12**, multiplied with the transformation ratio of the transformer. In this phase, a residual current, the magnetization current of the transformer **112**, flows through the secondary side diodes e.g., diodes D**5**-D**8**. Once this magnetization current has decayed, the transformer voltage is zero. The phase in which the transformer voltage is zero may also be obviated.

A preferred embodiment of the invention will be described in closer detail referring to FIG. **5**.

A resonant inverter **11** in the form of a full-bridge circuit with the four semi-conductor switches a-d is mounted downstream of the solar generator **10** having a buffer capacitor **16** or of another DC source.

The full-bridge circuit is connected to the transformer **112** through the capacitor **17**. The rectifier **113** is mounted downstream of the transformer **112**. Together with the capacitor **17**, the leakage inductance (not shown) of this transformer forms a series resonance. If the resonance frequency obtained is higher than the switching frequency of the switches of the full-bridge circuit, the switches a-d can be switched on and off without loss.

The high-frequency inverter **111** and the high-frequency transformer **112** form, together with the secondary side rectifier **113**, a resonant converter circuit or the resonant inverter **11**.

The intermediate circuit capacitor **12** and the regen-capable inverter **13** (not shown herein) are mounted downstream of the resonant inverter **11**. As already shown in FIG. **1**, the regen-capable inverter **13** is connected to the energy supply network **15** that has not been illustrated here via the mains filter **14** that has not been illustrated herein.

Due to the resonant converter circuit, the voltages at the capacitor **16** and the intermediate circuit capacitor **12** are hard-coupled. This means that, when subjected to load, the two voltages are proportional to each other according to the transformer's transformation ratio as long as the converter is operated in the full resonant mode.

At the beginning of the start-up phase, the voltage at the solar generator **10** is so high that full resonant operation is not possible. Then, the resonant inverter **11** is operated in the hard-switching mode.

FIG. **4** shows schematically the curve of the primary current in the hard-switching mode. The diagonally opposite semi-conductor switches a and d and b and c respectively of the inverter **11** and **111** respectively, are each opened simultaneously. They may be opened between zero and 50% of the period. If they are activated at 50%, the current obtained would be almost sinusoidal. For shorter switch-on times, the sinusoidal current is phase-controlled and the current obtained is as shown by way of example in FIG. **4**. FIG. **4** also shows the voltage curve plotted above the primary winding of the transformer **112**.

As soon as the intermediate circuit voltage at the intermediate circuit capacitor **12** has built up, the regen-capable inverter **13** begins to feed energy into the energy supply network **15**. As a result, the energy source, i.e., the solar generator **10**, is loaded. As a result, the voltage at the solar generator **10** drops. If, under the load, the voltage has dropped to such an extent that too high a voltage can no longer occur in the intermediate circuit capacitor **12**, the resonant inverter **11** or **111** switches over to the full resonant mode. Then, the start-up process has come to an end.

FIG. **3** shows the schematic curve of the primary current of the transformer **112** in the resonant mode. Within half a period, an almost sinusoidal current forms. The resonant frequency, i.e., the current frequency, is adjusted so as to be higher than the clock frequency of the semi-conductor switches, e.g., a-d, of the inverter **11** or **111** respectively. The semi-conductor switches, e.g., a-d, of the inverter **11** or **111** respectively may be activated between approximately 30% and 50% of the period. The appropriate actuation is greater than half the period of the resonance frequency of the oscillating circuit consisting of the resonant capacitor **17** and the transformer's leakage inductance. As the current flows through the primary winding of the transformer **112**, the capacitor **17** is charge exchanged. FIG. **3** also shows the voltage curve plotted above the primary winding of the transformer **112**. This voltage is determined by the voltages at the direct voltage intermediate circuit (intermediate circuit capacitor **12**) and at the resonant capacitor **17**.

As a rule, it is necessary to transform the voltage if the resonant inverter **11** or **111** and the regen-capable inverter **13** are to be equipped with semi-conductor switches, e.g., a-d, of the same electric strength. The semi-conductor switches, e.g., a-d, in the resonant inverter **11** or **111** must be devised for the no-load voltage of the solar generator **10**. The semi-conductor switches, e.g., a-d, in the regen-capable inverter **13** must be devised for the voltage at the intermediate circuit capacitor **12** that is obtained in the MPP in the full resonant mode. As a rule, transformation is necessary because, at a transformation of 1:1 or less in the MPP, the voltage obtained at the intermediate circuit capacitor **12** would be so low that mains electricity supply would not be possible.

In a dimensioning example, it is assumed that the electric strength of the semi-conductors is 1200 V and the voltage of the DC source or of the solar generator **10** ranges from 450 V to 900 V. If the transformation ratio is e.g., 1:1.33 and the minimum input voltage is 450 V, an intermediate circuit voltage of 600 V is still achieved at the capacitor **12**. This voltage is the minimum voltage necessary to feed a three-phase 400 V low voltage network. If the DC source voltage is between 450 V and 675 V, the resonant inverter **11** can be operated in the full resonant mode without the voltage at the capacitor **12** exceeding 900 V. The DC source voltage range of between 450 V and 675 V accordingly is the MPP range of the DC voltage source. For voltages of between 675 V and 900 V of the DC source, the resonant inverter **11** is operated in the hard-switch mode so that the intermediate circuit voltage at the capacitor **12** will not exceed 900 V. Voltages of 675 V and 900 V only occur when the DC source is unloaded, that is to say in the no-load condition or in the start-up phase.

Accordingly, the regen-capable inverter **13** can be equipped with semi-conductor switches, e.g., a-d, that are suited for operation in the MPP in the full resonant mode of operation but that are not suited for operation in the no-load condition of the input voltage source. As a result, semi-conductor switches a-d and e.g., corresponding free-wheeling diodes having a lower off-state voltage and, as a result thereof, lower losses can be used. Furthermore, such semi-conductors are less expensive. The resonant inverter **11** may also be equipped with semi-conductor switches, e.g., a-d, of another electric strength than those used for the regen-capable inverter **13**.

All the known semi-conductor switches capable of being switched off may be utilized as the switches, for example IGBT's, MOSFET's, GTO's. A first implementation variant of the embodiment shown in FIG. **5** is illustrated in FIG. **6**. The inverter **11** or the high-frequency inverter **111** is here implemented as a half-bridge circuit with two semi-conductor switches A and B. Beside the capacitor **16**, there is also provided a connection in series of two additional capacitors **18** and **19** with a centre tap. The resonant circuit is formed by the leakage inductance of the transformer **112** and the capacitance of the capacitors **17**, **18** and **19**. If designed accordingly, the additional capacitor **17** may be obviated. Then, the resonant capacitance is only formed by the capacitors **18**, **19** of the half-bridge.

The fundamental function of the circuit as shown in the FIGS. **1** or **5** remains unchanged. This variant however only needs two semi-conductor switches. It does not need any transformer with a primary side centre tap.

Another implementation variant of the invention is shown in FIG. **7**. Here, the resonant converter **11** is implemented on the primary side as a centre tap connection with two semi-conductor switches A and B. In this case, the resonant capacitor **17** is disposed on the secondary side of the transformer **112**.

In this implementation variant, semi-conductor losses are minimized on the primary side of the transformer **112**. For this purpose, semi-conductor switches A and B having a higher off-state capacity must be utilized.

The fundamental function of the circuit as shown in the FIGS. **1** or **5** remains again unchanged. This variant also only needs two semi-conductor switches and is suited for low-source voltages. As contrasted to the embodiment above, it requires a transformer with a primary side centre tap.

A fourth example of the invention is shown in FIG. **8**. The resonant inverter **11** is here implemented on the primary side as a centre tap connection with semi-conductor switches A and B. Two resonant capacitors **20**, **21** connected in series are provided here. The resonant capacitors **20**, **21** are disposed as a constituent part of the rectifier **113** in the form of a half-bridge circuit on the secondary side. In principle, and as already shown in FIG. **7**, an additional resonant capacitor **17** can be inserted in series with the secondary winding of the high-frequency transformer **112**.

In this implementation variant, the semi-conductor losses are minimized on the primary side of the transformer. For this purpose, semi-conductor switches A and B having a higher off-state capacity must be utilized.

The fundamental function of the circuit as shown in the FIGS. **1** or **5** remains again unchanged. This variant only needs two semi-conductor switches and is suited for low-source voltages. It requires a transformer with a primary side centre tap.

Instead of a solar generator **10**, another energy source, preferably an energy source with a variable source voltage and in, particularly with a high internal impedance may be utilized, for example a fuel cell, a battery, a wind power plant with a permanent-magnet generator, a combustion engine with a permanent-magnet generator or a water power plant with a permanent-magnet generator (PM-generator). High internal impedance in the sense of the invention is given if the non-load voltage changes by more than 20%, more specifically by more than 40%, with respect to an operation point to which a load is applied.

Alternatively, instead of one single resonant inverter, several inverters, more specifically several high-frequency inverters **111**, may also be provided on the primary side on the transformer **112**. These inverters are virtually mounted in parallel at the energy source and are connected to a common intermediate capacitor **12** on the secondary side with respect to the transformer **112**. The discrete high-frequency inverters (**111**.1 through **111**.n) are clocked at different times so that lower ripple current loads are generated in the energy source and in the intermediate circuit capacitor **12**.

Also, what has not been shown, a leakage inductance of the transformer **112** can be complemented by one or several additional inductances in order to achieve the desired resonance frequency.

LIST OF NUMERALS

1 feeding device
10 solar generator
11 resonant inverter
12 direct voltage intermediate circuit
13 regen-capable inverter
14 mains filter
15 energy supply network
16 buffer capacitor
17 resonant capacitor
18, **19** further capacitors
20, **21** resonant capacitors
111 high-frequency inverter
112 high-frequency transformer
113 high-frequency rectifier

I claim:

1. A device **[**(**1**)**]** for feeding electrical energy from an energy source with variable source voltage into an electric power supply network **[**(**15**)**]**, **[**said**]** *the* device **[**(**1**) including**]** *comprising:*

a transformer **[**(**112**) for galvanic isolation,**]***;*

a **[**resonant**]** *high frequency* inverter **[**(**11**) with semi-conductor**]** *comprising first* switches **[**(a-d; A, B),**]** *and* one or several **[**resonant**]** capacitors **[**(**17**; **18**, **19**; **20**, **21**)**]***;* and

[one**]** *a* rectifier **[**(**113**)**]**, **[**characterized in that**]**

wherein the device **[**(**1**)**]** does not comprise a boost chopper or a buck chopper, **[**and that**]**

wherein the **[**resonant**]** *high frequency* inverter **[**(**11**)**]** is **[**operated**]** *configured to operate* in a full resonant mode if an operating voltage is in a maximum power **[**operation**]** point (MPP) that exists in normal operation, **[**whereby**]** *wherein* in the maximum power point (MPP) **[**the**]** *a* current from the transformer **[**(**112**) is a current made from**]** *comprises* sinusoidal half-waves, and

wherein the **[**resonant**]** *high frequency* inverter **[**(**11**)**]** is **[**operated**]** *configured to operate* in a hard-switching mode if the voltages exceed the maximum **[**operation**]** *power* point (MPP), so that the current from the transformer **[**(**112**)**]** comprises sine-wave portions, **[**whereby**]** *wherein* the hard-switching mode only occurs in a start-up phase.

[2. The device as set forth in claim **1**,

characterized in that, in the operation point (MPP), the semi-conductor switches (a-d; A, B) of the resonant inverter (**111**) are operated with a duty cycle that is more than half a period of a resonance frequency of an oscillating circuit comprising one resonant capacitor or several resonant capacitors and of a transformer leakage inductance, at pulse widths ranging between 30 and 50% of a period of a pulse frequency, so that a voltage at an intermediate circuit capacitor (**12**) will not fall below a minimum value needed for feeding the network (**15**), even if a voltage at the maximum power point (MPP) of the energy source adopts a minimum voltage value imposed by the device, and that, if the voltages of the energy source are higher than the maximum power point voltage, said semi-conductor switches are operated at pulse widths of between zero and 50% so that the voltage at the intermediate circuit capacitor (**12**) will not exceed a maximum value given by an electric strength of the semi-conductor switches (a-d, A, B) of a regen-capable inverter (**13**), even if the voltage of the energy source is higher than the (MPP) voltage.]

3. The device as set forth in claim **1**[, characterized in that] *further comprising a regen-capable inverter comprising second switches, and wherein the first switches and the second switches have about* [semi-conductor switches of] the same electric strength [as semi-conductor switches (a-d; A,B) are used in the resonant inverter (**11**) and in the regen-capable inverter (**13**)].

[**4**. The device as set forth in claim **1**,

characterized by an implementation such that, in the hard-switching operation above the operation point (MPP), a transformer current of the transformer (**112**) consists of sine-wave portions.]

5. The device as set forth in claim **1**,

[characterized in that] *wherein* the transformer [(**112**)] is a high-frequency transformer [(**112**)] and is operated at a frequency that is higher than a frequency of the [energy] *electric power* supply network [(**15**)].

6. The device as set forth in claim **1**, [characterized in that a] *wherein the switches of the* high-frequency inverter [(**111**), which is part of the inverter (**11**) and comprises the semi-conductor switches (a-d; A, B), which are performed as] MOS transistors, [IGBT's, or GTO's, is mounted upstream of the transformer (**112**)] *IGBTs or GTOs*.

7. The device as set forth in claim [**2**] *3*,

[characterized in that] *wherein* the regen-capable inverter [(**13**)] is a one-phase or a three-phase inverter.

8. The device as set forth in claim **1**,

[characterized in that] *wherein* the *transformer, the high frequency inverter and the rectifier form a* resonant inverter [(**11**)], *and wherein the resonant inverter* comprises a full bridge.

9. The device as set forth in claim **1**,

[characterized in that] *wherein* the *transformer, the high frequency inverter and the rectifier form a* resonant inverter [(**11**)], *and wherein the resonant inverter* comprises a half-bridge.

10. The device as set forth in claim **9**,

[characterized in that] *wherein* the resonant inverter [(**11**) is performed as] *comprises* a [centre] *center* tap connection circuit.

11. The device as set forth in claim **1**,

[characterized in that] *wherein* the rectifier [(**113**) is devised as] *comprises* a half-bridge.

12. The device as set forth in claim **1**,

[characterized in that] *wherein* the one or several [resonant] capacitors [(**17**; **16**, **19**; **20**, **21**)] are connected in series or in parallel with a resonant circuit with respect to a primary winding of the transformer [(**112**)].

13. [A] *The* device [for feeding electrical energy] as set forth in claim **1**,

[characterized in that a resonant capacitor (**20**, **21**) is] *wherein the one or several capacitors are* connected in series or in parallel with a secondary winding of the transformer [(**112**)].

14. The device as set forth in claim **1**,

[characterized in that the] *wherein* the one or several [resonant] capacitors [(**18**, **19**)] of a half-bridge located on [the] *a* primary side of the transformer [(**112**)] are [utilized] *configured to operate* as resonant capacitors.

15. The device as set forth in claim **1**,

[characterized in that] *wherein* the one or several resonant capacitors [(**20**, **21**)] of a [secondary side] half-bridge *located on a secondary side of the transformer* are [utilized] *configured to operate* as resonant capacitors.

16. The device as set forth in claim **1**,

[characterized in that a] *wherein the* high-frequency inverter [(**111**)], the transformer [(**112**)] and the rectifier [(**113**)] form a resonant converter that is a DC/DC converter, a natural frequency formed by the one or more resonant capacitors [(**17**; **18**, **19**; **20**, **21**)] of a leakage inductance of the transformer [(**112**)] being higher than a switching frequency of the resonant inverter [(**11**)] in order to minimize switching losses in the [semi-conductor] switches [(a-d; A, B)] of the [resonant] *high frequency* inverter [(**11**)] as compared to a hard-switching mode of operation.

17. [A] *The* device [for feeding electrical energy] as set forth in claim **1**,

[characterized in that] *wherein* a leakage inductance of the transformer [(**112**)] is complemented by one or several additional inductances in order to achieve a desired resonance frequency.

[**18**. The device as set forth in claim **1**,

characterized in that, on a primary side, several resonant inverters (**11**) are mounted in parallel at the energy source and, on a secondary side, are connected to a common intermediate circuit capacitor (**12**) discrete resonant inverters (**11**) being clocked at different times.]

19. The device as set forth in claim **1**,

[characterized in that the] *wherein the transformer, the high frequency inverter and the rectifier form a* resonant inverter [(**11**)], *and wherein the resonant inverter* is connected to a regen-capable inverter [(**13**)].

20. A system [with a] *comprising the* device as set forth in claim **1** and [with] the energy source,

[characterized in that] *wherein* the energy source is *a* solar generator [(**10**)], a fuel cell, a battery, a wind power plant with a permanent-magnet generator, a combustion engine with a permanent-magnet generator or a water power plant with a permanent-magnet generator (PM-generator).

21. [Use of a] *A method for using the* device as set forth in claim **1**, *wherein the device is used* in [a public energy] *the electric power* supply network supplying a plurality of consumers or an island network with one or several consumers.

22. A method of operating [a] *the* device as set forth in claim **1**, *wherein* the energy source [of which is] *comprises* a photovoltaic solar generator [with] *having a solar generator characteristic line*[at least one] *with the* maximum power point (MPP) [of a solar generator characteristic line], the [resonant inverter (**11**)] *device* being operated in the full resonant mode in the MPP and in the hard-switching mode when the voltage exceeds the MPP.

[**23**. The device as set forth in claim **1**,

characterized in that high-performance semi-conductors capable of being switched off are mounted in parallel with the diodes D**5** through D**8** of the resonant rectifier (**113**) so that a circuit may be operated in both directions if the energy source is an energy accumulating device.]

24. A method for feeding electrical energy from an energy source with a variable source voltage to an electrical power supply network, the method comprising:

converting a first DC power to a second DC power in a resonant converter, wherein the resonant converter operates in a hard switching operation mode, and wherein a current of a transformer of the resonant converter comprises sine-wave portions if a DC voltage exceeds a maximum power point (MPP) of the energy source that occurs only in a start-up phase; and

converting a first DC power to a second DC power in the resonant converter, wherein the resonant converter *operates in a soft switching operation mode, and wherein a current of the transformer of the resonant converter comprises sinusoidal half-waves if the DC voltage is in the maximum power point (MPP) of the energy source that exists in normal operation.*

25. The method as set forth in claim 24, wherein the resonant converter is buck chopper free and boost chopper free.

26. The method as set forth in claim 25, wherein operating the resonant converter in the soft switching mode comprises operating the converter with a resonance frequency, and wherein the resonance frequency is higher than a clock frequency of switches of an inverter.

27. The method as set forth in claim 25, further comprising

filtering the second DC power;

inverting the filtered second DC power to an AC power;

filtering the AC power; and

feeding the filtered AC power into the electrical power supply network.

28. The method as set forth in claim 25, wherein the resonant converter comprises an inverter, the transformer and a rectifier, and wherein the inverter is electrically coupled to a primary winding of the transformer, wherein the rectifier is electrically coupled to a secondary winding of the transformer.

29. The method as set forth in claim 28, wherein operating the resonant converter in the soft switching mode comprises operating switches of the inverter at pulse widths between about 30% and about 50% of a period of a clock frequency, and wherein operating the resonant converter in the hard switching mode comprises operating the switches of the inverter at pulse widths between about zero and about 50% of the period of the clock frequency.

30. The method set forth in claim 28, wherein operating the resonant converter in the soft switching mode comprises switching switches of the inverter at a time when a current in the primary winding of the transformer is about zero.

* * * * *

Espacenet

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Three-phase solar converter for mains and island power operations adapts voltage levels from DC voltage generated by solar cells to the public mains power supply by raising and converting power.

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Abstract of DE19937410 (A1)

A solar converter is fed by a solar cell module (1). Input voltage of the solar converter is buffered by an input capacity (2) and fed to a converter (3) in a B2 bridge circuit (5). A high-frequency transformer (4) adapts, usually raises, KHz DC voltage from the solar modules. A non-controllable rectifier in a B2 bridge circuit is wired to an RC snubber (6) to reduce overshooting during changeover procedures.

Notice

DESCRIPTION DE19937410A1

[0001]

13 The invention relates to a circuit arrangement for a three-phase solar inverter for grid and island operation with a step-up converter for adapting the voltage level of the solar module blocks to the grid voltage level and with a three-phase inverter for adapting to the frequency and sinusoidal shape of the grid according to the generic type specified in the preamble of claim 1 .

[0002]

20 Photovoltaic systems are primarily used to feed electrical consumers in an island network or to feed energy into an existing supply network.

22 In periods in which the energy requirement is greater than the amount of energy provided by the system, additional energy is taken from the public network or from an existing storage device for electrical energy (accumulator) when connected to the grid. If there is neither a grid connection nor an energy storage device, the power consumption must be adapted to the energy input of the solar system by connecting and disconnecting consumers.

[0003]

30 In the magazine PHOTON May-June 1998 pages 62, 63 solar inverters are presented in a market overview, in which an input DC voltage, which corresponds to the output voltage of the solar modules, is provided to a downstream grid-connected inverter through a special connection of the solar modules.

34 The output voltage is adapted to the voltage level of the public supply network of 230 V / 400 V by means of a special regulation based on the variation of the pulse width when the inverter is activated. Due to the direct connection of the grid-side inverter to the output of the solar module, the hardware expenditure and the device costs were reduced by saving a step-up converter.

However, there is no possibility here of influencing the course of the inverter input DC voltage by means of an additional regulation, as is possible with an additional voltage regulation by varying the pulse width of an additional step-up converter on the input side. Fluctuations in the output voltage of the solar modules can only be compensated to a very limited extent by varying the pulse width when controlling the inverter. The relatively high voltage level at which the solar modules have to work through a series connection of several elements also proves to be unfavorable here.

45 For example, the input DC voltage for an inverter in B6 circuit for the 230 V / 400 V three-phase system must be in the range of around 600 V.

[0004]

50 There are known circuit arrangements of inverters which adjust the DC voltage level of the solar modules to the frequency of 50 or 60 Hz and the voltage level of 230 V / 400 V of conventional power supplies on the network side behind an output-side inverter.

53 The advantage of such a circuit arrangement consists in a lower voltage level in the output-side inverter, which corresponds to the output voltage of the solar modules. In contrast to the use of an inverter directly at the grid access with a significantly higher grid voltage level, higher losses occur in the inverter due to higher currents with the same power. The subsequent adaptation of the voltage level to the mains voltage, which is usually 230 V / 400 V, is then carried out using a transformer. Because of the frequency of 50 or 60 Hz, an inexpensive standard model can be used here. Since the maximum energy that can be transmitted in the core material of the transformer falls as the frequency falls, it must be designed in a fairly large design here, which leads to arrangements that require a large amount of space and are very heavy.

[0005]

65 DE 196 03 823 mentions a circuit arrangement for an inverter which is constructed from three completely identically constructed single-phase and self-sufficient inverters to generate a three-phase three-phase system.

68 These work in parallel on a DC voltage supply rail. The output voltage consists of three alternating voltages, which then do not generate a three-phase system with three voltages offset by 120 °. However, numerous consumers, especially in the industrial sector, require a three-phase system with three voltages offset by 120 ° (e.g. B. three-phase asynchronous motors).

[0006]

76 EP 0780750 A2 mentions a control method and a device arrangement in which an output inverter in a B2 bridge circuit converts the DC voltage of the DC voltage intermediate circuit into an AC voltage corresponding to the frequency and voltage amplitude of the network to be supplied or the consumers to be supplied.

80 The two-phase version of the inverter requires quite a lot of smoothing effort due to the power pulsing at twice the line frequency, which is expressed in a larger intermediate circuit inductance and a larger intermediate circuit capacitor.

[0007]

86 Circuit arrangements of line-commutated inverters are also known in which a line-commutated inverter feeds energy into the network.

88 In the magazine PHOTON May-June 1998 p. 15 a three-phase inverter from the company ACE GbR based on thyristors is mentioned, in which the feed takes place without a transformer through a choke coil. This variant has the advantage of a relatively simple circuit structure. The disadvantage, however, is that the input voltage of the inverter must be high and a favorable transmission behavior can only be achieved at values above 400 V. With decreasing input voltages, the ignition angle approaches a value of 90 degrees, which means that only reactive power is fed back into the network.

[0008]

98 A method and an inverter for converting direct current into three-phase current are also known (DE 43 02 687), in which the voltage pulses of the secondary side of the transformer are directly divided between the three phases of the inverter on the output side, so that a symmetrical three-phase system results.

102 This makes it possible to save the intermediate circuit capacitor. However, it must be taken into account that the decoupling effect of an intermediate circuit capacitor is then no longer present and there is therefore no longer any energy storage element in the entire circuit arrangement. Both voltage systems, the voltage of the solar system and that of the supply network, are thus directly coupled or interconnected so that load changes and other disturbances, especially rapid transient processes in one of the two voltage systems, impact the other voltage system without being dampened.

[0009]

112 The object of the present invention is therefore to keep the structural size of the transformer small by means of transformer voltage adaptation with a transmission frequency of several kilohertz.

115 Furthermore, a subsequent rectification and a second inverter, which is then connected to the grid, are used to adapt to the frequency of the grid, usually 50 or 60 Hz, and a largely low-harmonic and sinusoidal voltage with an effective value of 230 V / 400 V generated. The power factor can be variably set by means of a corresponding control.

[0010]

122 If the energy is to be processed in a particularly efficient manner, a uniform energy supply from the intermediate circuit must be realized.

124 The circuit arrangement according to the invention fulfills this requirement through the three-phase structure of the inverter on the output side. Here the frequency of the oscillating power corresponds to six times the mains frequency and the smoothing effort is reduced accordingly, which leads to a smaller design for the intermediate circuit choke and the intermediate circuit capacitor. According to the advantageous embodiment of the invention mentioned here, it is provided that a three-phase system consisting of three output voltages offset by 120 ° is generated by a special synchronization of the three phases of the inverter or with a determination of the drive signals of the inverter that takes into account the required phase shift of 120 ° from the outset .

[0011]

136 In certain cases of application, a connection of the inverter to a public supply network is not provided or not possible.

138 Because of the necessary supply voltages for the electronic assemblies, an additional energy store or an additional energy source is required. This can be the public supply network, but also an accumulator. If the network is not available and there is also no accumulator unit, which is usually very costly and maintenance-intensive, the invention described here offers the possibility of also generating the auxiliary voltages from the energy of the solar cells. The inverter according to the invention has a voltage supply which is also fed from the connected solar cells parallel to the power section. When a certain minimum energy input of the modules is exceeded, a special power supply unit takes over the supply of the electrical assemblies of the solar inverter. This power supply unit provides various electrically isolated supply voltages, for example for the control electronics of the input inverter, the microcontroller control unit and the control electronics of the line-side inverter.

[0012]

152 With certain consumers, it is necessary to cover an increased energy requirement when the device is switched on.

154 Such consumers are e.g. B. electric drives, (e.g. B. Pump drives). However, since the energy input from the solar system is not sufficient to provide this increased output, start-up problems can arise. In order to reduce the inrush current, according to the invention, the output frequency and voltage of the inverter are reduced by a special control method when operating electrical drives. The possibility of setting the amount and frequency of the inverter output voltage makes it possible to track the operating point of the drive when the energy input of the solar cells decreases and to ensure continuous operation of the drive by lowering the frequency and reducing the power.

[0013]

165 Both a midpoint connection and a bridge connection are possible for the circuitry implementation of the aforementioned components of input-side inverters and output-side inverters (network inverters).

168 If the inverter is designed in a bridge circuit, the voltage load on the valves is reduced by a factor of 0.5 compared to the midpoint circuit. Particularly with regard to the required intermediate circuit voltage of around 600 V, the choice of the bridge type was based on a bridge circuit, both on the input side and on the output side. In order to regulate the output voltage with fluctuating input voltages and different loads, the switching elements of the input inverter are controlled in such a way that the input terminals of the transformer are connected to an adjustable voltage-time area. For this purpose, the input-side semiconductor components are controlled with a pulse train of constant frequency and a fixed pulse duty factor of 0.5, but the phase shift between the right and left half of the bridge is varied so that different voltage-time areas are transformed to the secondary side at the input terminals of the transformer (phase -Shifting).

[0014]

182 Because of the leakage inductance and parasitic capacitances of the transformer, a high-frequency transient process occurs at switching frequencies in the kilohertz range.

184 This leads to an increased voltage load on the rectifier diodes, which can be twice the primary voltage multiplied by the transformation factor of the transformer. According to the invention, an RC circuit (RC snubber) at the output reduces the overshoot in the switching process in accordance with the dimensioning of the RC network.

[0015]

191 Since the rectified transformer output voltage consists of stepped-up, pulse-width modulated rectangular blocks of the DC supply voltage of the solar modules, additional smoothing measures are necessary.

194 By connecting an intermediate circuit inductance and an intermediate circuit capacitor downstream, the course of the rectified voltage and the rectified current is smoothed out.

[0016]

199 Since the energy input is particularly dependent on the weather in solar systems, an additional energy store can be used to provide continuous energy.

201 According to the invention, a switching converter for adapting the different voltage levels is connected in parallel to the solar cell and feeds the actual physical energy store. These are usually accumulators or hydrogen fuel cells / hydrolysers that are operated with a low voltage. The switching on and off of the energy storage device, depending on the energy input / energy consumption (energy management), is performed by a separate control module.

[0017]

209 A transformer coupling of the inverter output voltage with the voltage of the solar modules and an additional optoelectronic potential separation guarantee that the solar modules and the control electronics are free of potential even when the output inverter is connected to the network, so that the device can be easily connected to other electrical and electronic components (e.g.

214 B. Personal computer, PLC control,. . .) can be interconnected.

[0018]

218 The circuit arrangement according to the invention has corresponding control inputs, as a result of which several inverters can be synchronized with one another and thus the performance of the isolated networks to be generated is subsequently increased.

221 An inverter working as a master specifies the voltage amplitude, the frequency and the phase position of this network.

[0019]

226 Further details of the invention are shown in the following Fig.

1

230 "Circuit design of the solar inverter" and Fig.

2

234 "Regulation and control scheme" can be seen.

[0020]

238 The circuit arrangement of the solar inverter according to the invention is fed by a solar cell module (1).

240 The input voltage of the solar inverter is buffered with the help of an input capacitance (2) and fed to an inverter in a B2 bridge circuit (3).

242 The following high-frequency transformer (4) adjusts, usually a step-up position, of the pulsed DC voltage of the solar modules in the kilohertz range. A downstream uncontrolled rectifier in a B2 bridge circuit (5) is connected to an RC snubber (6) to reduce the overshoot when switching over. The DC voltage and the DC current are smoothed with the aid of an intermediate circuit capacitor (7) and an intermediate circuit choke (8). The downstream inverter in the B6 bridge circuit (9) generates a three-phase symmetrical three-phase voltage

system (10) from the direct voltage by means of a pulse-width-modulated control of the power semiconductor components S1 to S6. An automatic control unit for the step-up converter (12) and an automatic control unit for the inverter (13) generate the control signals for the power semiconductors. The setpoint for the voltage regulation (11) of the step-up converter and the pulse-width-modulated signals from the inverter are specified by a microcontroller (14).

[0021]

256 In summary, it is stated that the circuit arrangement according to the invention is a qualitative further development of existing systems, particularly with regard to optional mains or island operation, the use of energy storage devices and the possibility of variable setting of frequency and voltage for special energy consumers.

Notice

CLAIMS DE19937410A1

1.

13 Circuit arrangement of a solar inverter for converting the DC voltage of solar modules into a three-phase system with 3 output voltages offset by 120 °, characterized in that the input DC voltage is converted into a high-frequency alternating pulsed AC voltage by means of an input inverter and a voltage boost or voltage is increased with the help of a downstream transformer. Voltage reduction takes place, the output alternating voltage of the transformer is subsequently rectified and a downstream intermediate circuit capacitor is charged and in which a downstream inverter pulsing this intermediate circuit voltage generates an approximately sinusoidal output voltage, which corresponds in amplitude and frequency to the mains voltage and which is generated by the Pulse width modulation is relatively low in harmonics.

2.

25 Circuit arrangement according to Claim 1, characterized in that an energy store is switched on on the DC voltage side (e.g. B. accumulator, hydrogen fuel cell / hydrolyser) and by means of a switching converter, the voltage level of the DC voltage is matched to the input voltage of the energy storage device, with the energy storage being switched on and off by a separate control unit according to the energy input of the solar system.

3.

33 Circuit arrangement according to Claim 1, characterized in that an inverter is operated in the input stage (input inverter) and this generates a high-frequency voltage pulse sequence in the kilohertz range which is transmitted by a high-frequency transformer.

4.

39 Circuit arrangement according to Claim 1, characterized in that an input inverter according to Claim 2, which is operated in a two-pole bridge circuit and is designed as a push-pull stage with a sequential automatic control unit using a pulse sequence of constant frequency, but with variable phase shifting, the semiconductor components T1 and T3 as well as T2 and T4 is controlled.

5.

47 Circuit arrangement according to Claim 1, characterized in that the rectifier (output rectifier) connected downstream of the transformer is designed as a two-pole uncontrolled bridge circuit and is connected to an RC snubber to reduce the voltage load on the rectifier valves.

6.

53 Circuit arrangement according to Claim 1, characterized in that the intermediate circuit inductance connected downstream of the output rectifier and the downstream intermediate circuit capacitor decouple the input stage from the output stage and at the same time have a smoothing effect on the direct current and the direct voltage.

7.

60 Circuit arrangement according to Claim 1, characterized in that the output-side inverter is designed as a bridge circuit (B6) and generates three voltage phases offset by 120 ° so that three-phase consumers can be connected.

8.

66 Circuit arrangement according to Claim 1, characterized in that the 3 phases of the output inverter can be connected to the network or serve to feed an island network or one or more consumers.

9.

72 Circuit arrangement according to Claim 1, characterized in that the output-side inverter for generating a low-frequency, low-harmonic output voltage is controlled via a pulse-width-modulated voltage pulse sequence in the middle kilohertz range.

10.

78 Circuit arrangement according to Claim 1, characterized in that a separate power supply unit is provided to provide the auxiliary energy for the input and output stages of the solar inverter and

the microcontroller control unit, which is itself fed by the solar cells, which switches on when there is a corresponding energy input and an auxiliary voltage supply to the beforehand takes over the named components.

11.

86 Circuit arrangement according to Claim 1, characterized in that the input-side inverter is operated by means of a corresponding control of the pulse width (phase shifting method) at a constant pulse frequency with a voltage control and the output-side inverter is controlled with pulse-width-modulated control pulses to generate a sinusoidal output voltage.

12.

93 Circuit arrangement according to claim 1, characterized in that a complete potential separation between the output-side inverter and the feeding voltage of the solar modules is realized by a transformer voltage coupling and further to the control electronics by an optoelectronic signal transmission (three-way separation).

13.

100 Circuit arrangement according to Claim 1, characterized in that several solar inverters can be connected in parallel according to the master-slave principle via corresponding control inputs of the information processing electronics, with one device specifying the voltage, frequency and phase of the inverter output voltages.

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(54) Dreiphasiger Solarwechselrichter für Netz- und Inselbetrieb

(57) Es wird ein dreiphasiger Solarwechselrichter für den Netz- und Inselbetrieb vorgestellt, welcher aus der von Solarzellen bereitgestellten Gleichspannung durch ein Hochsetzen und Wechselrichten eine Anpassung des Spannungsniveaus an das öffentliche Stromversorgungsnetz vornimmt. Dabei wird ein Drehstromsystem mit drei um 120 verschobenen symmetrischen Phasenspannungen erzeugt. Der Betrieb der Anlage ist sowohl mit Anbindung als auch ohne Kopplung zum öffentlichen Versorgungsnetz und wiederum mit und ohne zusätzlichen Energiespeicher (in der Regel einem Akkumulator) möglich. Die Ausgangsspannung der Solarmodule wird dabei wechselgerichtet und mit einer Frequenz von mehreren Kilohertz über einen Transformator hochgesetzt und gleichgerichtet, anschließend erneut, entsprechend der Parameter des elektrischen Versorgungsnetzes wechselgerichtet. Eine Entkopplung der Hochstelleinheit vom ausgangsseitigen Wechselrichter erfolgt über einen Kondensator im Gleichspannungszwischenkreis. Der eingangsseitige Wechselrichter arbeitet als analoge Schaltung mit einer Spannungsregelung, der Ausgangswechselrichter wird von einem Mikrocontrollersystem nach dem MPP (Maximal-Power-Point) Prinzip angesteuert. Die Spannungsversorgung der Komponenten erfolgt über die Solarzellen mit einem separaten Netzteil, so daß ein Betrieb unabhängig von Hilfsenergiequellen (Netzanschluß, Akkumulator) möglich ist.

DE 199 37 410 A 1

Beschreibung

Die Erfindung betrifft eine Schaltungsanordnung für einen dreiphasigen Solarwechselrichter für den Netz- und Inselbetrieb mit einem Hochsetzsteller zur Anpassung des Spannungsniveaus der Solarmodulblöcke an den Netzspannungspegel und mit einem dreiphasigen Wechselrichter zur Anpassung an die Frequenz und Sinusform des Netzes gemäß der im Oberbegriff des Anspruchs 1 angegebenen Gattung.

Photovoltaikanlagen dienen in erster Linie zur Speisung elektrischer Verbraucher eines Inselnetzes oder zur Einspeisung von Energie in ein bestehendes Versorgungsnetz. In Zeiträumen, in denen der Energiebedarf größer als die von der Anlage bereitgestellte Energiemenge ist, wird bei einer Netzanbindung zusätzliche Energie aus dem öffentlichen Netz oder aus einem vorhandenen Speicher für elektrische Energie entnommen (Akkumulator). Existiert weder eine Netzanbindung noch ein Energiespeicher, so ist die Leistungsabnahme durch Zu- und Abschalten von Verbrauchern an den Energieeintrag der Solaranlage anzupassen.

In der Zeitschrift PHOTON Mai–Juni 1998 Seite 62, 63 werden in einer Marktübersicht Solarwechselrichter vorgestellt, bei denen durch eine spezielle Verschaltung der Solarmodule einem nachgeschalteten netzgekoppelten Wechselrichter eine Eingangsgleichspannung, die der Ausgangsspannung der Solarmodule entspricht, bereitgestellt wird. Durch eine spezielle Regelung, die auf der Variation der Pulsweite bei der Ansteuerung des Wechselrichters beruht, wird die Ausgangsspannung an das Spannungsniveau des öffentlichen Versorgungsnetzes von 230 V/400 V angepaßt. Durch die direkte Beschaltung des netzseitigen Wechselrichters mit dem Ausgang des Solarmoduls wurden der Hardwareaufwand und die Gerätekosten durch die Einsparung eines Hochsetzstellers verringert. Allerdings besteht hier nicht die Möglichkeit, durch eine zusätzliche Regelung auf den Verlauf der Wechselrichtereingangsgleichspannung Einfluß zu nehmen, wie es bei einer zusätzlichen Spannungsregelung über eine Variation der Pulsweite eines zusätzlichen eingangsseitigen Hochsetzstellers möglich ist. Schwankungen in der Ausgangsspannung der Solarmodule können nur sehr bedingt durch eine Variation der Pulsweite bei der Wechselrichteransteuerung ausgeglichen werden. Als ungünstig erweist sich hier weiterhin das relativ hohe Spannungsniveau, auf dem die Solarmodule durch eine Reihenschaltung mehrerer Elemente arbeiten müssen. So muß zum Beispiel die Eingangsgleichspannung für einen Wechselrichter in B6-Schaltung für das 230 V/400 V Drehstromsystem im Bereich von rund 600 V liegen.

Es sind Schaltungsanordnungen von Wechselrichtern bekannt, die eine Anpassung des Gleichspannungspegels der Solarmodule an die Frequenz von 50 oder 60 Hz und das Spannungsniveau von 230 V/400 V üblicher Energieversorgungen auf der Netzseite hinter einem ausgangsseitigen Wechselrichter vornehmen. Der Vorteil einer solchen Schaltungsanordnung besteht in einem geringeren Spannungspegel im ausgangsseitigen Wechselrichter, welcher der Ausgangsspannung der Solarmodule entspricht. Im Gegensatz zur Verwendung eines Wechselrichters direkt am Netzzugang mit deutlich höherem Netzspannungspegel treten jedoch, bedingt durch größere Ströme bei gleicher Leistung, höhere Verluste im Wechselrichter auf. Die nachfolgende Anpassung des Spannungsniveaus an die Netzspannung von in der Regel 230 V/400 V erfolgt dann mit einem Transformator. Wegen der Frequenz von 50 oder 60 Hz kann hier ein preiswertes Standardmodell verwendet werden. Da mit fallender Frequenz die maximal übertragbare Energie im Kernmaterial des Transformators sinkt, muß dieser hier in einer recht großen Bauform ausgelegt werden, was zu Anordnungen mit einem großen Platzbedarf und einem großen Gewicht führt.

In DE 196 03 823 wird eine Schaltungsanordnung für einen Wechselrichter erwähnt, die zur Generierung eines dreiphasigen Drehstromsystems aus drei völlig identisch aufgebauten einphasigen und autark arbeitenden Wechselrichtern aufgebaut ist. Diese arbeiten parallel an einer Gleichspannungsversorgungsschiene. Die Ausgangsspannung besteht aus drei Wechselspannungen, die jedoch dann kein Drehstromsystem mit drei um 120° versetzten Spannungen erzeugen. Zahlreiche Verbraucher, besonders im industriellen Bereich, erfordern aber ein Drehstromsystem mit drei um 120° versetzten Spannungen (z. B. Drehstromasynchronmotoren).

In EP 0780750 A2 werden ein Steuerverfahren und eine Geräteanordnung erwähnt, bei denen ein Ausgangswechselrichter in B2-Brückenschaltung die Wandlung der Gleichspannung des Gleichspannungszwischenkreises in eine Wechselspannung entsprechend Frequenz und Spannungsamplitude des zu versorgenden Netzes bzw. der zu versorgenden Verbraucher vornimmt. Die zweiphasige Ausführung des Wechselrichters erfordert wegen der mit doppelter Netzfrequenz pulsierenden Leistung einen recht hohen Glättungsaufwand, der sich in einer größeren Zwischenkreisinduktivität und einem größeren Zwischenkreiskondensator äußert.

Ebenfalls sind Schaltungsanordnungen von netzgeführten Wechselrichtern bekannt, bei denen ein netzgeführter Wechselrichter eine Energieeinspeisung in das Netz vornimmt. So wird in der Zeitschrift PHOTON Mai–Juni 1998 S. 15 ein dreiphasiger Wechselrichter von der Firma ACE GbR auf Thyristorbasis erwähnt, bei dem die Einspeisung transformatorlos durch eine Drosselspule erfolgt. Diese Variante hat den Vorteil eines relativ einfachen schaltungstechnischen Aufbaus. Der Nachteil besteht jedoch darin, daß die Eingangsspannung des Wechselrichters groß sein muß und erst bei Werten über 400 V ein günstiges Übertragungsverhalten erzielt werden kann. Bei kleiner werdenden Eingangsspannungen nähert sich der Zündwinkel immer mehr einem Wert von 90 Grad, was zur Folge hat, daß nur noch Blindleistung in das Netz zurückgespeist wird.

Auch sind ein Verfahren und ein Wechselrichter zur Umwandlung von Gleichstrom in Drehstrom bekannt (DE 43 02 687), bei dem eine direkte Aufteilung der Spannungsimpulse der Sekundärseite des Transformators auf die drei Phasen des ausgangsseitigen Wechselrichters erfolgt, so daß sich ein symmetrisches Dreiphasensystem ergibt. Dadurch ist es möglich, den Zwischenkreiskondensator einzusparen. Zu berücksichtigen ist jedoch, daß die entkoppelnde Wirkung eines Zwischenkreiskondensators dann nicht mehr vorhanden ist und sich somit kein Energiespeicherglied mehr in der gesamten Schaltungsanordnung befindet. Beide Spannungssysteme, die Spannung der Solaranlage und die des Versorgungsnetzes, werden somit direkt verkoppelt bzw. zusammengeschaltet, so daß Laständerungen und andere Störungen, insbesondere schnelle transiente Vorgänge in einem der beiden Spannungssysteme, ungedämpft auf das andere Spannungssystem durchschlagen.

Aufgabe der vorliegenden Erfindung ist es deshalb, durch eine transformatorische Spannungsanpassung mit einer Übertragungsfrequenz von mehreren Kilohertz die Baugröße des Transformators gering zu halten. Des weiteren wird durch eine, nachfolgende Gleichrichtung und einen zweiten, dann mit dem Netz verbundenen Wechselrichter die Anpassung an die Frequenz des Netzes, in der Regel 50 oder 60 Hz, vorgenommen und eine weitestgehend oberschwingungsarme und sinusförmige Spannung mit einem

Effektivwert von 230 V/400 V generiert. Der Leistungsfaktor kann durch eine entsprechende Steuerung variabel eingestellt werden.

Soll die Energieaufbereitung besonders wirkungsgradgünstig erfolgen, so ist ein gleichmäßiger Energiebezug aus dem Zwischenkreis zu realisieren. Die erfindungsgemäße Schaltungsanordnung erfüllt diesen Anspruch durch den dreiphasigen Aufbau des ausgangsseitigen Wechselrichters. Hier entspricht die Frequenz der oszillierenden Leistung der sechsfachen Netzfrequenz und der Glättungsaufwand reduziert sich dementsprechend, was zu einer geringeren Bauform für die Zwischenkreisdrossel und den Zwischenkreiskondensator führt. Gemäß der vorteilhaften Ausgestaltung der hier erwähnten Erfindung ist vorgesehen, durch eine spezielle Synchronisation der drei Phasen des Wechselrichters bzw. mit einer von vornherein die benötigte Phasenverschiebung von 120° berücksichtigenden Ermittlung der Ansteuersignale des Wechselrichters ein aus drei um 120° versetzten Ausgangsspannungen bestehendes Drehstromsystem zu erzeugen.

In bestimmten Einsatzfällen ist eine Anbindung des Wechselrichters an ein öffentliches Versorgungsnetz nicht vorgesehen bzw. nicht möglich. Wegen der notwendigen Versorgungsspannungen der elektronischen Baugruppen wird ein zusätzlicher Energiespeicher bzw. eine zusätzliche Energiequelle benötigt. Diese kann sowohl das öffentliche Versorgungsnetz, aber auch ein Akkumulator sein. Steht das Netz nicht zur Verfügung und existiert auch keine Akkumulatoreinheit, die in der Regel sehr kosten- und wartungsintensiv ist, so besteht bei der hier beschriebenen Erfindung die Möglichkeit, die Hilfsspannungen ebenfalls aus der Energie der Solarzellen zu erzeugen. Der erfindungsgemäße Wechselrichter besitzt eine Spannungsversorgung, die parallel zum Leistungsteil ebenfalls von den angeschlossenen Solarzellen gespeist wird. Beim Überschreiten eines bestimmten minimalen Energieeintrags der Module übernimmt ein spezielles Netzteil die Versorgung der elektrischen Baugruppen des Solarwechselrichters. Dieses Netzteil realisiert die Bereitstellung verschiedener potentialgetrennter Versorgungsspannungen, so für die Ansteuerelektronik des Eingangswechselrichters, die Microcontrollersteuereinheit sowie die Ansteuerelektronik des netzseitigen Wechselrichters.

Bei bestimmten Verbrauchern ist es erforderlich, im Einschaltmoment einen erhöhten Energiebedarf abzudecken. Solche Verbraucher sind z. B. elektrische Antriebe, (z. B. Pumpenantriebe). Da der Energieeintrag der Solaranlage aber nicht ausreicht, um diese erhöhte Leistung bereitzustellen, kann es zu Anlaufproblemen kommen. Um nun den Einschaltstrom zu reduzieren, werden erfindungsgemäß durch ein spezielles Steuerverfahren beim Betrieb von elektrischen Antrieben die Ausgangsfrequenz und -spannung des Wechselrichters reduziert. Durch die Möglichkeit der Einstellung von Betrag und Frequenz der Wechselrichterausgangsspannung ist es möglich, bei sich verminderndem Energieeintrag der Solarzellen den Arbeitspunkt des Antriebs nachzuführen und durch eine Frequenzabsenkung, verbunden mit einer Leistungsabsenkung den kontinuierlichen Betrieb des Antriebs zu gewährleisten.

Für die schaltungstechnische Umsetzung der vorab erwähnten Komponenten eingangsseitiger Wechselrichter und ausgangsseitiger Wechselrichter (Netzwechselrichter) ist sowohl eine Mittelpunktschaltung als auch eine Brückenschaltung möglich. Wird der Wechselrichter in Brückenschaltung ausgelegt, so vermindert sich die Spannungsbelastung der Ventile um den Faktor 0.5 gegenüber der Mittelpunktschaltung. Insbesondere in Hinblick auf die erforderliche Zwischenkreisspannung von rund 600 V wurde bei der Auswahl des Brückentyps sowohl eingangsseitig als auch ausgangsseitig auf eine Brückenschaltung orientiert. Um die Regelung der Ausgangsspannung bei schwankenden Eingangsspannungen und unterschiedlichen Belastungen zu realisieren, werden die Schaltelemente des Eingangswechselrichters so gesteuert, daß die Eingangsklemmen des Transformators mit einer einstellbaren Spannungs-Zeitfläche beschaltet werden. Dazu werden die eingangsseitigen Halbleiterbauelemente mit einer Impulsfolge konstanter Frequenz und einem festen Tastverhältnis von 0.5 angesteuert, wobei jedoch die Phasenverschiebung zwischen der rechten und der linken Brückenhälfte variiert wird, so daß an den Eingangsklemmen des Transformators unterschiedliche Spannungs-Zeitflächen auf die Sekundärseite transformiert werden (Phase-Shifting).

Wegen der Streuinduktivität und parasitären Kapazitäten des Transformators kommt es bei Schaltfrequenzen im Kilohertzbereich zu einem hochfrequenten Einschwingvorgang. Dieser führt zu einer erhöhten Spannungsbelastung der Gleichrichterdioden, die das Doppelte der Primärspannung multipliziert mit dem Übersetzungsfaktor des Transformators betragen kann. Erfindungsgemäß wird durch eine RC-Beschaltung (RC-Snubber) am Ausgang das Überschwingen im Schaltvorgang entsprechend der Dimensionierung des RC-Netzwerkes reduziert.

Da die gleichgerichtete Transformatorausgangsspannung aus hochtransformierten, pulsweitenmodulierten Rechteckblöcken der Speisegleichspannung der Solarmodule besteht, machen sich zusätzliche Glättungsmaßnahmen erforderlich. Durch das Nachschalten einer Zwischenkreisinduktivität und eines Zwischenkreiskondensators wird glättend auf den Verlauf der gleichgerichteten Spannung und des gleichgerichteten Stromes eingewirkt.

Da besonders bei Solaranlagen der Energieeintrag stark von der Witterung abhängig ist, kann durch einen zusätzlichen Energiespeicher eine kontinuierliche Energiebereitstellung realisiert werden. Erfindungsgemäß wird dabei ein Schaltwandler zur Anpassung der unterschiedlichen Spannungsebenen parallel zur Solarzelle geschaltet, welcher den eigentlichen physikalischen Energiespeicher speist. Dabei handelt es sich in der Regel um Akkumulatoren oder Wasserstoffbrennstoffzellen/Hydrolyseure, die mit einer Kleinspannung betrieben werden. Das Zu- und Abschalten des Energiespeichers, abhängig vom Energieeintrag/Energieverbrauch (Energiemanagement), übernimmt dabei ein separates Steuermodul.

Durch eine transformatorische Kopplung der Wechselrichterausgangsspannung mit der Spannung der Solarmodule und einer zusätzlichen optoelektronischen Potentialtrennung wird auch bei Anbindung des Ausgangswechselrichters an das Netz eine Potentialfreiheit der Solarmodule und der Ansteuerelektronik garantiert, so daß sich das Gerät problemlos mit anderen elektrischen und elektronischen Komponenten (z. B. Personalcomputer, SPS-Steuerung, ...) verschalten läßt.

Die erfindungsgemäße Schaltungsanordnung besitzt entsprechende Steuereingänge, wodurch mehrere Wechselrichter miteinander synchronisiert werden können und somit die Leistung der zu generierenden Inselnetze nachträglich erhöht wird. Ein als Master arbeitender Wechselrichter gibt dabei die Spannungsamplitude, die Frequenz und die Phasenlage dieses Netzes vor.

Weitere Einzelheiten der Erfindung sind in der nachfolgenden **Fig.** 1 "Schaltungstechnischer Aufbau des Solarwechselrichters" und **Fig.** 2 "Regelungs- und Steuerungsschema" ersichtlich.

Die erfindungsgemäße Schaltungsanordnung des Solarwechselrichters wird von einem Solarzellenmodul (**1**) gespeist. Die Eingangsspannung des Solarwechselrichters wird mit Hilfe einer Eingangskapazität (**2**) gepuffert und einem Wechselrichter in B2-Brückenschaltung zugeführt (**3**). Der nachfolgende Hochfrequenztransformator (**4**) führt eine Anpassung, in der Regel eine Hochsetzstellung, der im Kilohertzbereich gepulsten Gleichspannung der Solarmodule durch. Ein nachfolgender ungesteuerter Gleichrichter in B2-Brückenschaltung (**5**) wird zur Verminderung des Überschwingens bei Umschaltvorgängen mit einem RC-Snubber (**6**) beschaltet. Mit Hilfe eines Zwischenkreiskondensators (**7**) und einer Zwischenkreisdrossel (**8**) werden die Gleichspannung und der Gleichstrom geglättet. Der nachgeschaltete Wechselrichter in B6-Brückenschaltung (**9**) erzeugt aus der Gleichspannung ein dreiphasiges symmetrisches Drehspannungssystem (**10**) durch eine pulsweitenmodulierte Ansteuerung der Leistungshalbleiterbauelemente S1 bis S6. Ein Ansteuerautomat für den Hochsetzsteller (**12**) und ein Ansteuerautomat für den Wechselrichter (**13**) übernehmen die Generierung der Ansteuersignale für die Leistungshalbleiter. Der Sollwert für die Spannungsregelung (**11**) des Hochsetzstellers sowie die pulsweitenmodulierten Signale des Wechselrichters werden von einer Microcontrollersteuerung (**14**) vorgegeben.

Zusammenfassend wird festgestellt, daß die erfindungsgemäße Schaltungsanordnung eine qualitative Weiterentwicklung von bestehenden Systemen besonders in Hinblick auf einen wahlweisen Netz- oder Inselbetrieb, auf den Einsatz von Energiespeichern und auf die Möglichkeit der variablen Einstellung von Frequenz und Spannung für spezielle Energieverbraucher ist.

Patentansprüche

1. Schaltungsanordnung eines Solarwechselrichters zur Umwandlung der Gleichspannung von Solarmodulen in ein Drehstromsystem mit 3 um 120° versetzten Ausgangsspannungen **dadurch gekennzeichnet**, daß die Eingangsgleichspannung mittels eines Eingangswechselrichters in eine hochfrequente alternierende gepulste Wechselspannung umgewandelt wird und mit Hilfe eines nachgeschalteten Transformators eine Spannungsanhebung bzw. Spannungsabsenkung erfolgt, wobei die Ausgangswechselspannung des Transformators im nachfolgenden gleichgerichtet wird und ein nachgeschalteter Zwischenkreiskondensator aufgeladen wird und bei der durch einen nachgeschalteten Wechselrichter durch eine Pulsung dieser Zwischenkreisspannung eine annähernd sinusförmige Ausgangsspannung erzeugt wird, die in der Amplitude und Frequenz der Netzspannung entspricht und die durch die Pulsweitenmodulation relativ oberschwingungsarm ist.
2. Schaltungsanordnung nach Anspruch 1, dadurch gekennzeichnet, daß ein Energiespeicher auf der Gleichspannungsseite zugeschaltet wird (z. B. Akkumulator, Wasserstoffbrennstoffzelle/Hydrolyseur) und mittels eines Schaltwandlers dabei das Spannungsniveau der Gleichspannung an die Eingangsspannung der Energiespeichereinrichtung angeglichen wird, wobei das Zu- und Abschalten des Energiespeichers von einer separaten Steuereinheit entsprechend dem Energieeintrag der Solaranlage erfolgt.
3. Schaltungsanordnung nach Anspruch 1, dadurch gekennzeichnet, daß ein Wechselrichter in der Eingangsstufe (Eingangswechselrichter) betrieben wird und dieser eine hochfrequente Spannungsimpulsfolge im Kilohertzbereich generiert, die von einem Hochfrequenztransformator übertragen wird.
4. Schaltungsanordnung nach Anspruch 1 dadurch gekennzeichnet, daß ein Eingangswechselrichter nach Anspruch 2, der in einer zweipoligen Brückenschaltung betrieben wird und als Gegentaktstufe ausgeführt ist mit einem sequentiellen Steuerautomaten durch eine Impulsfolge konstanter Frequenz, jedoch mit variabler Phasenverschiebung (phase-shifting) die Halbleiterbauelemente T1 und T3 sowie T2 und T4 ansteuert wird.
5. Schaltungsanordnung nach Anspruch 1, dadurch gekennzeichnet, daß der dem Transformator nachgeschaltete Gleichrichter (Ausgangsgleichrichter) als zweipolige ungesteuerte Brückenschaltung ausgeführt ist und zur Verminderung der Spannungsbelastung der Gleichrichterventile mit einem RC-Snubber beschaltet wird.
6. Schaltungsanordnung nach Anspruch 1, gekennzeichnet dadurch, daß die dem Ausgangsgleichrichter nachgeschaltete Zwischenkreisinduktivität und der nachgeschaltete Zwischenkreiskondensator eine Entkopplung der Eingangs- von der Ausgangsstufe durchführen und gleichzeitig glättend auf den Gleichstrom und die Gleichspannung wirken.
7. Schaltungsanordnung nach Anspruch 1, gekennzeichnet dadurch, daß der ausgangsseitige Wechselrichter in Brückenschaltung (B6) ausgeführt ist und drei um 120° versetzte Spannungsphasen erzeugt, somit Drehstromverbraucher angeschlossen werden können.
8. Schaltungsanordnung nach Anspruch 1, gekennzeichnet dadurch, daß die 3 Phasen des Ausgangswechselrichters mit dem Netz verbunden werden können oder zur Speisung eines Inselnetzes bzw. eines oder mehrerer Verbraucher dienen.
9. Schaltungsanordnung nach Anspruch 1, gekennzeichnet dadurch, daß der ausgangsseitige Wechselrichter zur Erzeugung einer niederfrequenten, oberschwingungsarmen Ausgangsspannung über eine pulsweitenmodulierte Spannungsimpulsfolge im mittleren Kilohertzbereich angesteuert wird.
10. Schaltungsanordnung nach Anspruch 1, gekennzeichnet dadurch, daß zur Bereitstellung der Hilfsenergie für die Eingangs- und Ausgangsstufe des Solarwechselrichters und der Microcontrollersteuereinheit ein separates Netzteil bereitgestellt wird, welches selbst von den Solarzellen gespeist wird, welches sich bei einem entsprechenden Energieeintrag einschaltet und eine Hilfsspannungsversorgung der vorab genannten Komponenten übernimmt.
11. Schaltungsanordnung nach Anspruch 1, gekennzeichnet dadurch, daß der eingangsseitige Wechselrichter über eine entsprechende Regelung der Pulsweite (Phase-Shifting-Verfahren) bei konstanter Pulsfrequenz mit einer Spannungsregelung betrieben wird und der ausgangsseitige Wechselrichter zur Generierung einer sinusförmigen Ausgangsspannung mit pulsweitenmodulierten Ansteuerimpulsen angesteuert wird.
12. Schaltungsanordnung nach Anspruch 1, gekennzeichnet dadurch, daß eine vollständige Potentialtrennung zwischen dem ausgangsseitigen Wechselrichter und der speisenden Spannung der Solarmodule durch eine transformatorische Spannungskopplung und weiterhin zur Steuerelektronik durch eine optoelektronische Signalübertragung realisiert wird (Drei-Wege-Trennung).
13. Schaltungsanordnung nach Anspruch 1, gekennzeichnet dadurch, daß über entsprechende Steuereingänge der informationsverarbeitenden Elektronik meh-

rere Solarwechselrichter nach dem Master-Slave-Prinzip parallel geschaltet werden können, wobei ein Gerät Spannung, Frequenz und Phase der Wechselrichterausgangsspannungen vorgibt.

Hierzu 2 Seite(n) Zeichnungen

- Leerseite -

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Offenlegungstag: 15. Februar 2001

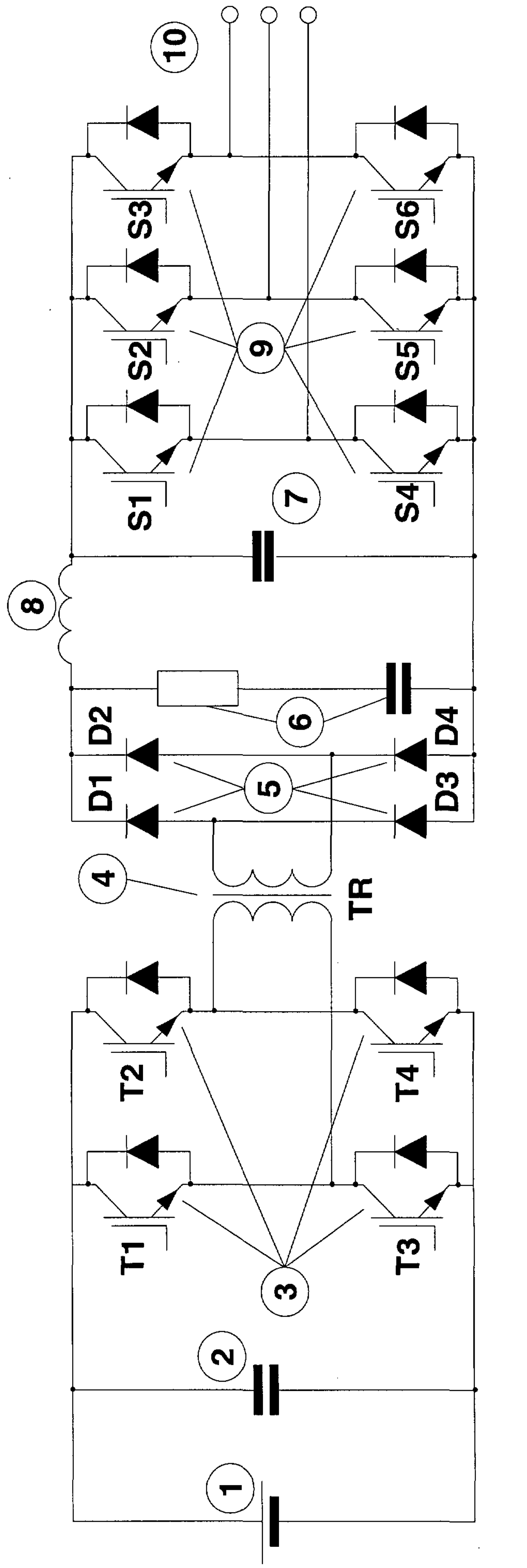

Fig. 1: Schaltungstechnischer Aufbau des Solarwechselrichters

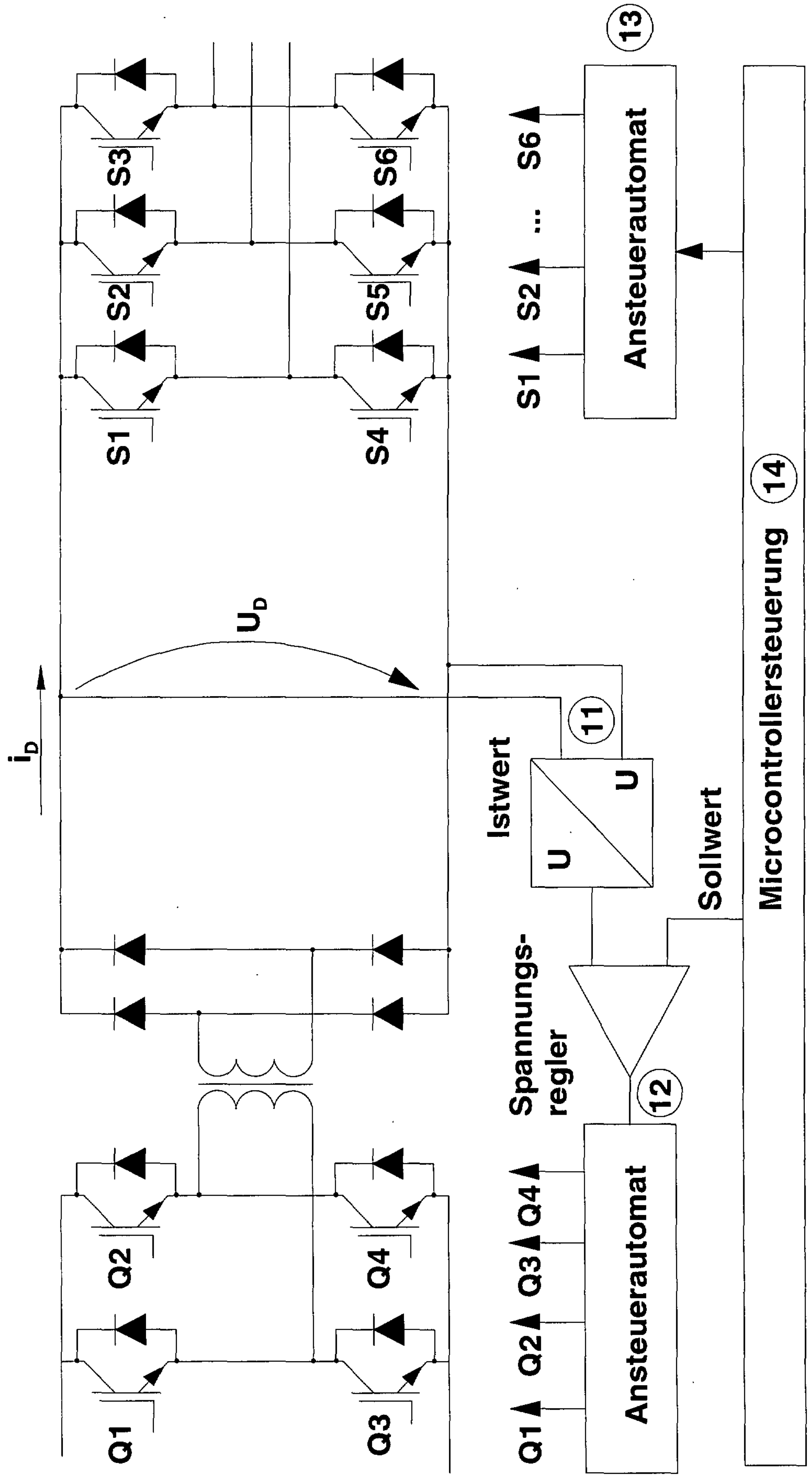

Fig. 2: Regelungs- und Steuerungsstruktur

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Victor et al.

(10) **Patent No.: US 8,614,901 B2**
(45) **Date of Patent: Dec. 24, 2013**

(54) **INVERTER EMPLOYING A BOOST CHOPPER CIRCUIT AND A RESONANT CONVERTER CIRCUIT**

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(73) Assignee: **SMA Solar Technology AG**, Niestetal (DE)

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(51) **Int. Cl.**

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H02M 7/519	(2006.01)
H02M 7/521	(2006.01)
H02M 7/523	(2006.01)

(52) **U.S. Cl.**
USPC **363/17**; 363/21.02; 363/39; 363/124; 323/299

(58) **Field of Classification Search**
USPC 363/17, 21.02, 56.02, 123, 124, 131, 363/132, 24–26, 39–41; 323/266, 299, 301, 323/302
See application file for complete search history.

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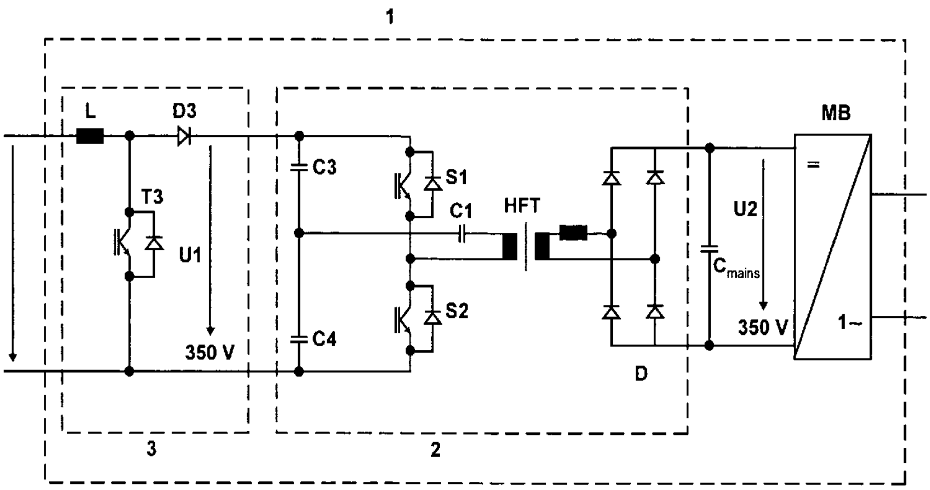
(57) **ABSTRACT**

An inverter with galvanic separation including a resonant converter and an upstream mounted boost chopper is intended to provide galvanic separation in the context of a variable input and output voltage as it exists in photovoltaic systems, with the efficiency being intended to be optimized over the entire input voltage range. This is achieved in that a boost chopper or a buck chopper is mounted upstream of the resonant converter.

23 Claims, 5 Drawing Sheets



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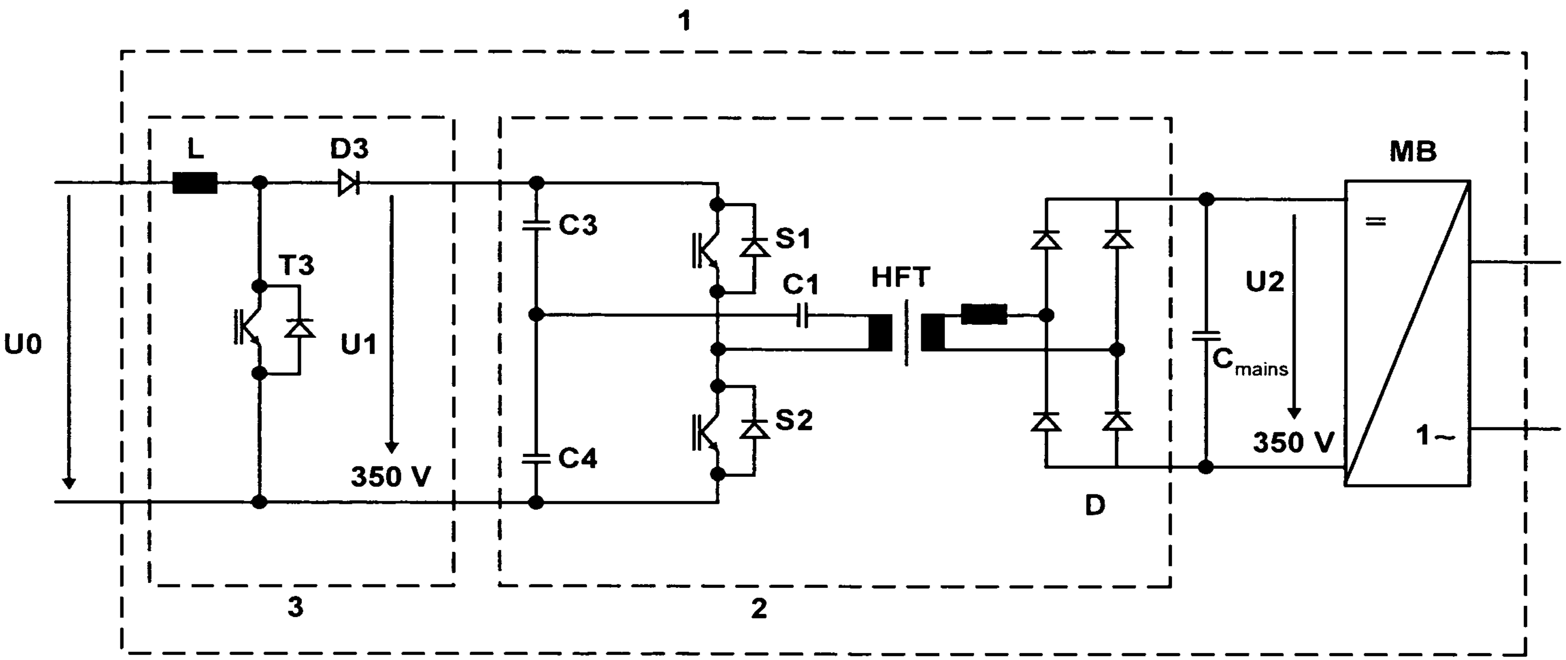

Fig. 1

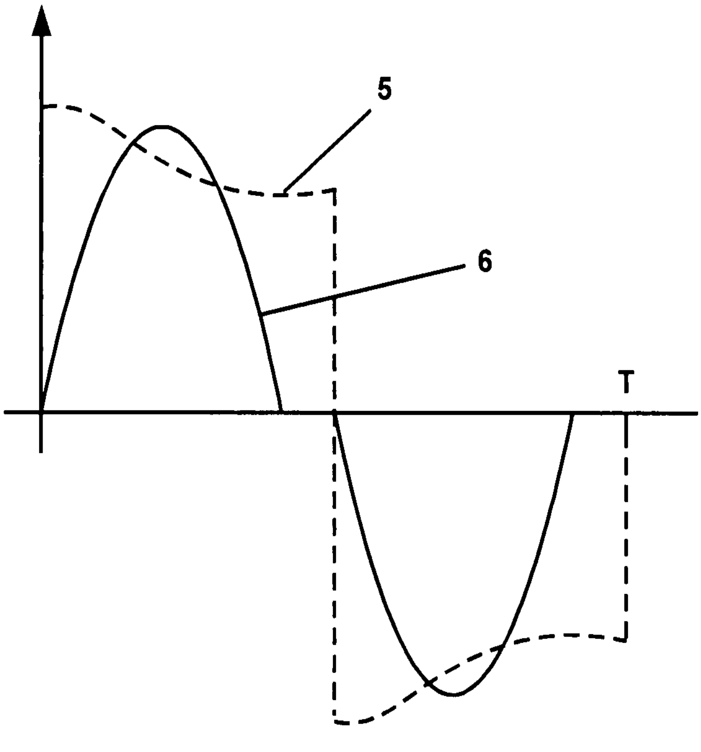

Fig. 2

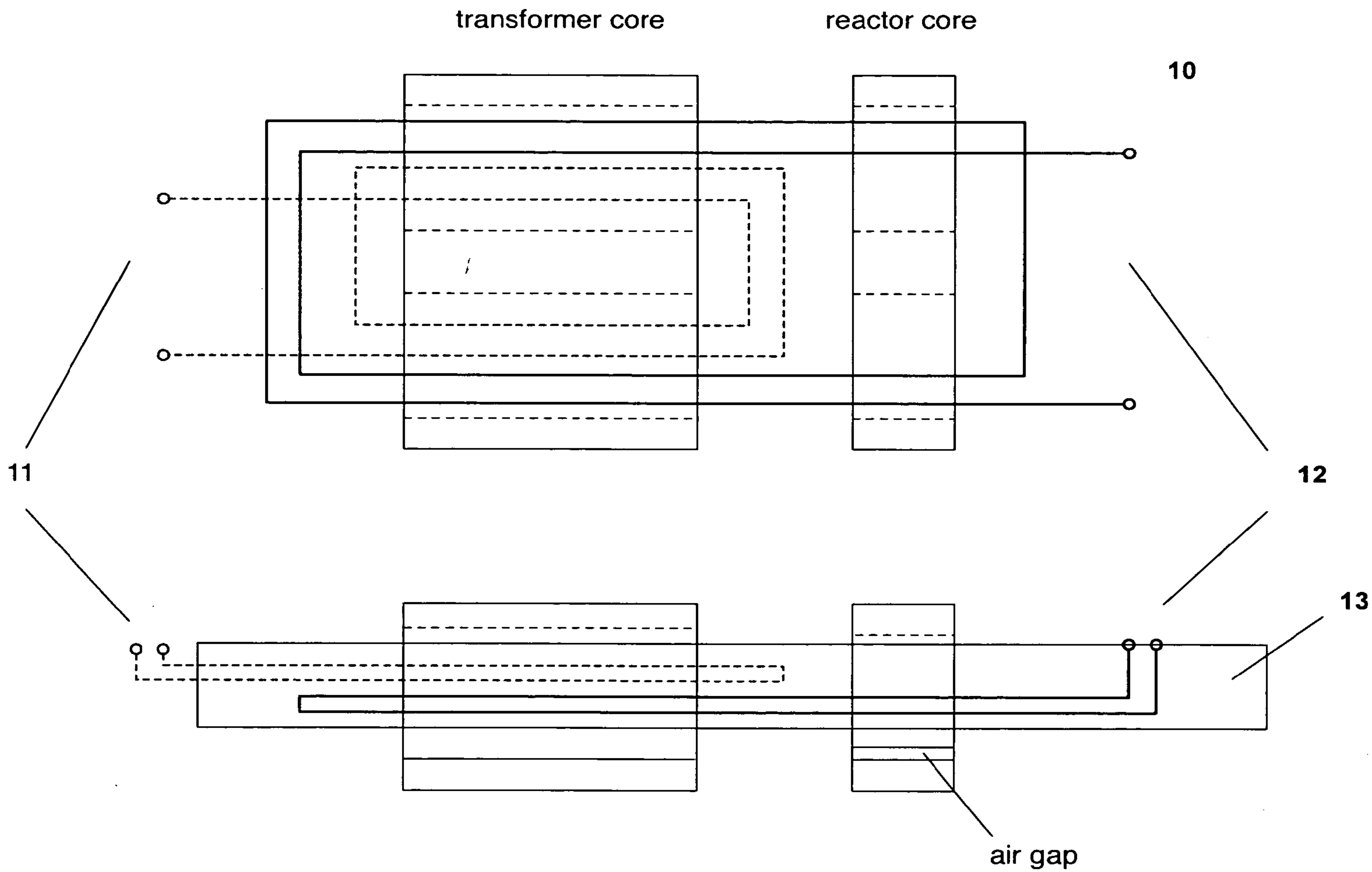

Fig. 3

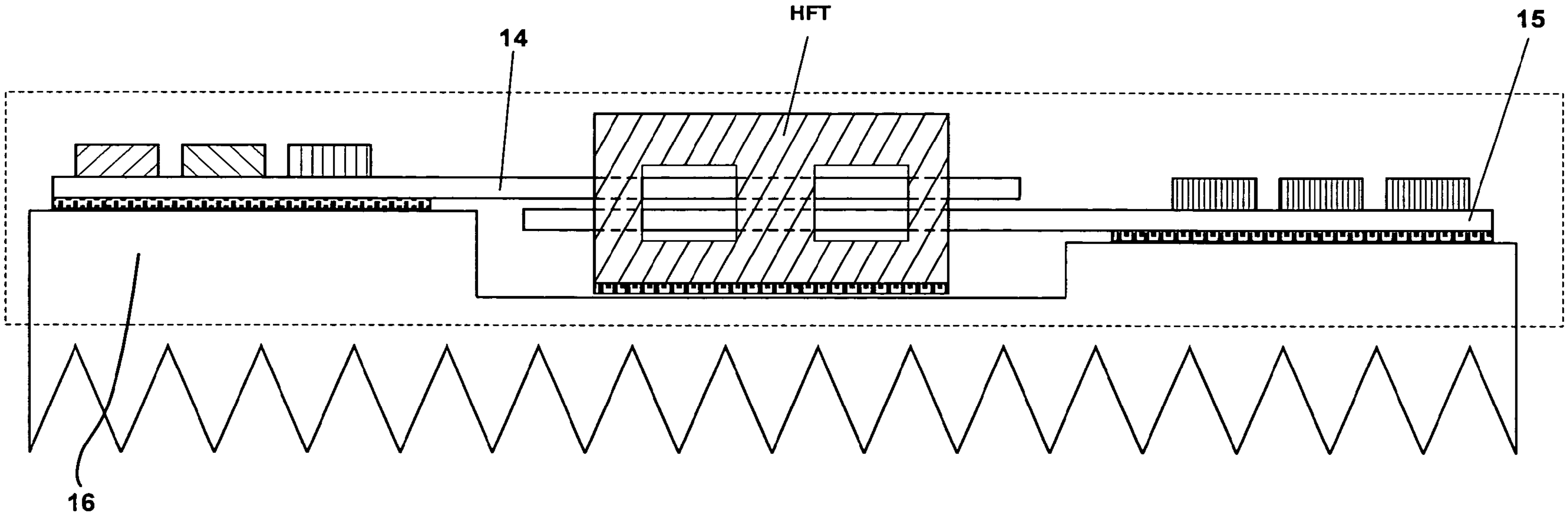

Fig. 4

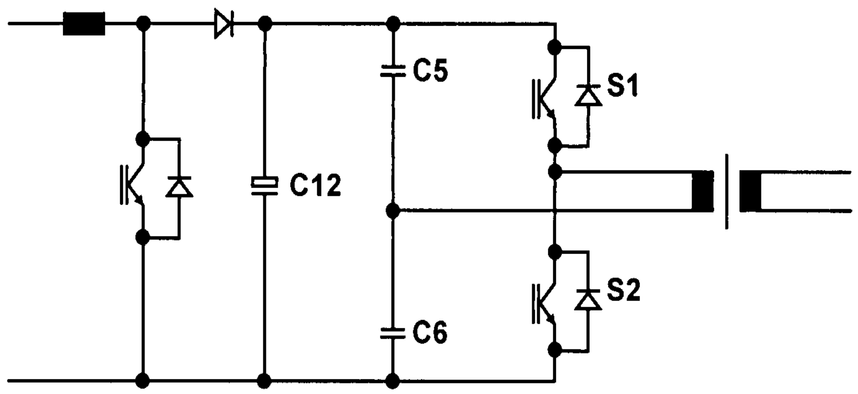

Fig. 5

INVERTER EMPLOYING A BOOST CHOPPER CIRCUIT AND A RESONANT CONVERTER CIRCUIT

FIELD

The invention relates to an inverter as set forth in the preamble of claim **1**.

BACKGROUND

An input converter for railbound vehicles is known from DE 198 27 872. It consists of a resonant converter with galvanic separation. Input/output voltage ratio is fixed. In loss optimized operation, the fixed input/output voltage ratio is determined by the transformation ratio of the transformer.

Due to varying ambiant conditions (solarization, temperature, . . .) and different generator designs, inverters in photovoltaic systems must be designed for a wide input voltage range and at the same time be highly efficient over this entire range.

SUMMARY

The invention is directed to an inverter which, in the context of a wide input voltage range as it is given in photovoltaic systems and of variable mains voltage, provides galvanic separation, with the efficiency being intended to be optimized over the entire input voltage range.

The invention enables optimum efficiency in operation of the inverters in the case of varying solarization and temperature of the photovoltaic modules or of different photovoltaic module configurations. The switching losses are minimized by the fact that the resonant converter operates independently of the input voltage at a constant operating point, this operating point being set over a wide input voltage range by the boost chopper. Provided the voltage at the resonant converter is stabilized, a boost chopper is more beneficial than a buck chopper insofar as the resonant converter achieves higher efficiency at higher stabilized input voltages.

The inverter of the invention combines advantages with respect to voltage adaptation and operation of a HF circuit without the tradeoff of adverse power and voltage ratings, high repetition rate of the adaptation stage, switching overvoltages and limited range of operation.

In an advantageous developed implementation of the converter of the invention, there is provided that the inverter is configured to be a single-phase inverter, with a power electronic half-bridge circuit, a series resonant capacitance and a high frequency transformer being provided. While the resonant converter operates at a constant operating point so that its input/output voltage ratio, which is dictated by the transformation ratio of the transformer, is fixed, the input voltage at the boost chopper may vary.

The boost chpper may advantageously be configured for permanent interval operation so that the free-wheeling diode of the boost chopper will never experience hard switching communication at turn-off. EMC transients are thus reduced and efficiency is increased as turn-on power losses are avoided.

The boost chopper need not be activated if the input voltage U_0 is high enough for the voltage at the capacitor C_{mains} to be sufficient for mains electricity supply. As a result, it is activated only if the actual mains voltage is so high that the actual PV voltage is not sufficient to set the voltage at the C_{mains}.

Efficiency is significantly improved using such a method since the losses are low in operating points without boost chopper operation. This is particularly efficient if the boost chopper reactors are particularly small due to the interval mode design, thus comprising very low ohmic resistances.

Appropriately, the repetition rate of the half-bridge circuit is lower than the resonance frequency. Said resonance frequency is obtained from the leakage inductance of the transformer and the series resonant capacitance. As a result, the semiconductors are zero-current switched, both on and off.

According to another advantageous developed implementation of the invention, there is provided a synchronous activation of the boost chopper and the resonant converter. Synchronous activation has the advantage to minimize the effective current load in the capacitors (C**3**, C**4**).

A particular effect of benefit is obtained if the transformer is configured to be a planar transformer having two printed circuit boards, with the primary winding being disposed on the one printed circuit board and the secondary winding on the other printed circuit board. The advantage thereof is that the printed circuit boards are coupled via a magnetic flux, which allows the expensive plug-and-socket connectors to be eliminated altogether. A cast housing, which is manufacturable at a lower cost than a corresponding sheet metal housing, comprises projections for good integration of such a planar transformer having two overlapping printed circuit boards with regard to cooling.

The leakage inductance of the planar transformer may be beneficially increased by introducing an additional reactor core with an air gap (FIG. **3**).

One exemplary embodiment is discussed in closer detail with reference to the drawings, with further advantageous developed implementations of the invention and their advantages being described.

BRIEF DESCRIPTION OF THE DRAWINGS

In the drawing:

FIG. **1** shows a schematic diagram of an inverter of the invention,

FIG. **2** shows a voltage/current diagram of the resonant converter,

FIG. **3** shows an illustration of a planar transformer,

FIG. **4** shows a sectional view of the planar transformer; and

FIG. **5** shows an advantageous switching variant of FIG. **1**.

DESCRIPTION

In the FIGS., like elements bear the same reference numerals.

FIG. **1** shows an inverter **1** of the invention for photovoltaic systems. It comprises a boost chopper **3**, a resonant converter **2** and a mains bridge MB. The resonant converter consists of a half-bridge circuit with the semiconductor switches S**1**, S**2** and a HF transformer HFT, which is provided with a series resonant capacitance or rather a capacitor C**1**, and of a semiconductor bridge D. Input/output ratio of the resonant converter **2** is fixed and dictated by the transformation ratio of the transformer. Together with the rectifier bridge D, the resonant converter forms an HF circuit.

In accordance with the invention, a boost chopper **3** is mounted upstream of the resonant converter **2**. Alternatively, a buck chopper may be mounted upstream of the resonant converter.

The boost chopper serves to adapt the voltage to voltage variations of the photovoltaic generator that may occur as a result of diverse operating conditions (solarization, temperature, . . .), different generator designs or dynamic adaptations to different mains voltage levels.

The boost chopper consists of a series reactor L, a switching element T**3** and a diode D**3** that are arranged in parallel to the half-bridge circuit and to two series-mounted capacitors C_3, C_4. The capacity of the capacitors C_3, C_4 is thereby greater than the series resonant capacitance (capacitor C_1).

The boost chopper operates in an input voltage range U_0 of 150 to 350 volt. The voltage U_1 applied downstream of the boost chopper is about 350 volt. The voltage U_2 at the output of the resonant converter also is 350 volt. If the input voltage is in excess of 350 volt, the boost chopper is not clocked and the voltages U_1 and U_2 increase proportionally with U_0.

The resonant DC/DC converter **2** is operated unidirectionally with the circuit shown in FIG. **1**. Other circuit arrangements for bidirectional operation are also possible, though.

The boost chopper **3** and the resonant converter **2** are activated synchronously in order to reduce the effective current load in the capacitors.

FIG. **2** shows the transformer voltage **5** and the transformer current **6** with the cycle duration of $T=1/f_{switch}$, wherein f_{switch} is the switching frequency of the HF circuit.

It is preferred that the repetition rate of the half-bridge circuit be lower than the resonance frequency, which is obtained from the leakage inductance of the transformer and the series resonant capacitance.

The transformer HFT is configured to be a planar transformer **10**, as illustrated in the FIGS. **3** and **4**. Said transformer comprises a primary winding **11** and a secondary winding **12** that are disposed on one printed circuit board **13** or on two printed circuit boards **14** and **15** (FIG. **4**). The printed circuit board is connected to an aluminium cast housing **16** via two insulating heat conducting foils. The line semiconductors are mounted on the printed circuit boards **14** and **15**, more specifically as SMD components.

FIG. **5** shows a circuit variant in which the load current conducting capacitor C**1** has been eliminated and the resonant capacitance is drawn into the DC circuit in the form of C**5** and C**6**. The capacitors C**3** and C**4** with quite high capacitance are replaced by the sole capacitor C_{12}. Two smaller resonance capacitors C**5**, C**6** with small capacitance are mounted in parallel thereto. The advantage of this circuit is that on the one side the sum of the capacitor currents is reduced so that the costs of the capacitors are lowered and that on the other side the switching losses are significantly reduced.

In the circuit shown in FIG. **5**, the switching losses are reduced over the circuit shown in FIG. **1** since the magnetizing current of the transformer causes the parasitic switch capacitances to be discharged during the recovery time in which the two switches are open with the switch voltage being reduced to the value of the voltage of the respective resonance capacitor minus half the intermediate circuit voltage, as a result thereof, before S**1** or S**2** are switched on again.

In the circuit shown in FIG. **1**, by contrast, the parasitic switch capacitances of S**1** and S**2** can only discharge to the value of the resonance capacitance C**1** during the recovery time before being switched on again so that the switching losses are accordingly higher.

The invention claimed is:

1. An inverter, comprising:

a boost chopper circuit configured to receive a DC input signal and generate a regulated DC voltage at an output thereof when the boost chopper circuit is activated, and configured to pass a voltage associated with the DC input signal to the output thereof when the boost chopper circuit is deactivated; and

a resonant converter circuit configured to receive a received voltage from the output of the boost chopper circuit, and generate a DC output voltage having galvanic separation with respect to the DC input signal from the received voltage,

wherein the boost chopper circuit is configured to be deactivated when the received voltage at the resonant converter, or a voltage associated therewith, is greater than a predetermined threshold value, wherein a duty cycle of the boost chopper circuit, when deactivated, is zero.

2. The inverter of claim **1**, wherein a switching of the boost chopper circuit, when activated, and a switching of the resonant converter are synchronous with one another.

3. The inverter of claim **1**, wherein the resonant converter comprises a half-bridge circuit coupled to a high frequency transformer through a series resonant capacitance.

4. The inverter of claim **3**, wherein a resonant frequency of the resonant converter is greater than a switching frequency thereof.

5. The inverter of claim **1**, wherein the boost chopper circuit, when activated, is configured to operate in an interval mode.

6. The inverter of claim **1**, wherein the resonant converter comprises a high frequency transformer.

7. The inverter of claim **6**, wherein the high frequency transformer comprises a primary winding and a secondary winding, and wherein a first terminal of the primary winding has a resonant capacitance associated therewith, that is in turn coupled to a common node of two series connected capacitors coupled across input terminals of the resonant converter.

8. The inverter of claim **7**, wherein first and second terminals of the secondary winding of the high frequency transformer are coupled to input terminals of a full bridge circuit.

9. The inverter of claim **6**, wherein the resonant converter comprises:

two series connected switches having a common node terminal coupled to a first terminal of a primary winding of the high frequency transformer;

two series connected capacitors connected in parallel with the two series connected switches, the two series connected capacitors having a common node coupled to a second terminal of the primary winding of the high frequency transformer.

10. The inverter of claim **9**, further comprising another capacitor connected in parallel with the two series connected capacitors.

11. The inverter of claim **10**, further comprising a series resonant capacitance coupled between the first terminal of the primary winding of the high frequency transformer and the common node of the two series connected capacitors.

12. The inverter of claim **6**, wherein the high frequency transformer comprises a planar transformer.

13. The inverter of claim **12**, wherein the planar transformer comprises a primary winding and a secondary winding, and wherein the primary winding is associated with one printed circuit board, and the secondary winding is associated with another printed circuit board.

14. The inverter of claim **12**, wherein the planar transformer comprises a primary winding and a secondary winding, and wherein the secondary winding is wrapped around a transformer core, and the primary winding is wrapped around a reactor core having an air gap and the transformer core.

15. The inverter of claim **1**, further comprising a photovoltaic generator coupled to generate the DC input signal and provide the DC input signal to the boost chopper circuit.

16. The inverter of claim **1**, further comprising a DC/AC converter coupled to the resonant converter circuit, and configured to receive the DC output voltage and generate an AC output voltage associated therewith.

17. An inverter having galvanic isolation, and configured to receive a varying DC input voltage, comprising:

a boost chopper circuit configured to receive the DC input voltage, and provide an intermediate DC voltage, wherein the intermediate voltage is substantially constant over variations in the DC input voltage for a range of DC input voltages below a predetermined threshold; and

a resonant converter downstream of the boost chopper circuit, and configured to receive the intermediate DC voltage, wherein the resonant converter operates at a constant operating point independent of variations in the DC input voltage.

18. The inverter of claim **17**, further comprising a bridge circuit downstream of the resonant converter, and configured to receive a second intermediate DC voltage from the resonant converter and generate an AC voltage associated therewith.

19. The inverter of claim **17**, wherein the resonant converter comprises:

an intermediate circuit having two series-connected capacitances connected together at a first center node, and configured to regulate the intermediate DC voltage;

a half-bridge circuit comprising two series-connected switches connected together at a second center node, the half-bridge circuit in parallel with the intermediate circuit;

a transformer having a first terminal of a first winding connected to the first center node via a series resonance capacitance, and a second terminal of the first winding connected to the second center node, and having a second winding with first and second terminals associated therewith; and

a semiconductor bridge circuit having a first input coupled to the first terminal of the second winding and a second input coupled of the second terminal of the second winding, and having first and a second outputs that together output the second intermediate DC voltage.

20. The inverter of claim **19**, wherein the semiconductor bridge circuit comprises:

a first pair of series-connected diodes connected together at a third center node;

a second pair of series-connected diodes connected together at a fourth center node,

wherein the first and second pair of diodes are in parallel with one another, and

wherein the first terminal of the second winding of the transformer is coupled to the third center node, and the second terminal of the second winding of the transformer is coupled to the fourth center node.

21. The inverter of claim **17**, wherein the boost chopper circuit is configured to pass the DC input voltage to the resonant converter when the DC input voltage is greater than the predetermined threshold.

22. The inverter of claim **17**, wherein the boost chopper circuit and the resonant converter are activated synchronously.

23. The inverter of claim **19**, wherein the transformer is a planar transformer.

* * * * *

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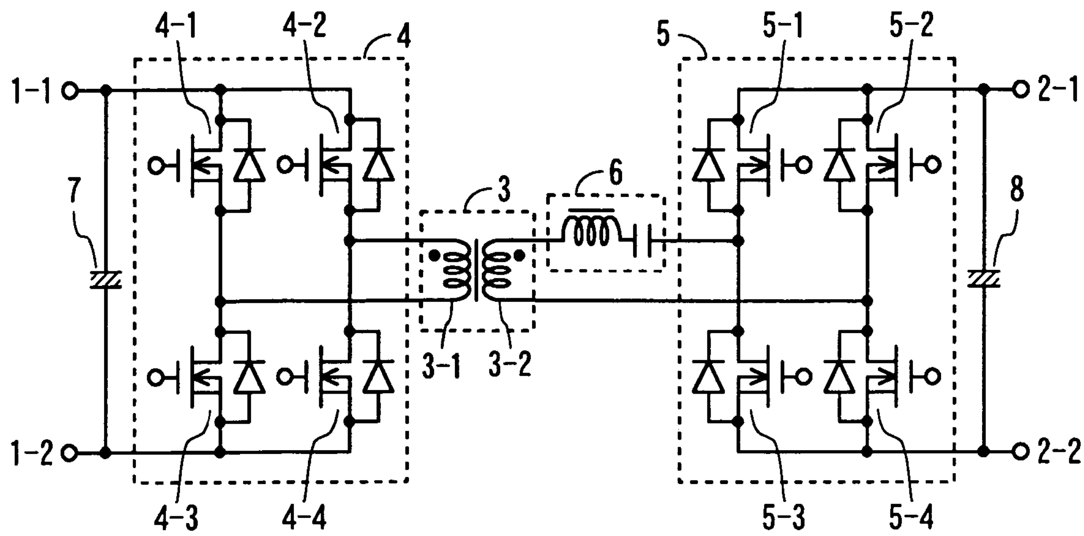
(54) **Two-way DC-DC converter**

(57) Rectifying elements are connected in parallel with switching elements (4-1 through 4-4) in a switching section (4) for the lower voltage side and rectifying elements are connected in parallel with switching elements (5-1 through 5-4) in a switching section (5) for the higher voltage side. An LC resonant circuit (6) is provided between the winding wire (3-2) for the high-voltage side in the transformer (3) and the switching section (5) for the higher voltage side; current which flows on the primary side and the secondary side is changed into a sinusoidal one; and switching is executed in the vicinity of the zero crossing points of the currents.

Fig. 1



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Description

[0001] The present invention relates to a two-way DC-DC converter, and more particularly, to a two-way DC-DC converter which can reduce switching losses and is able to simplify the control system.

[0002] For example, some of vehicles have two power supply systems with different voltages. When two-way exchange of electric power in such two direct-current (DC) power supply systems with different voltages is executed, it is common to adopt a configuration, in which a DC step-up circuit and a DC step-down circuit are disposed in parallel with each other between the DC power supply systems and the circuits are used, as necessary.

[0003] Moreover, there has been made a proposal in which, when two-way exchange of electric power between the DC power supply systems is executed, a two-way DC-DC converter is used in order to obtain an enough high DC voltage by a small-scale circuit.

[0004] For example, the Japanese Patent Application Laid-open No. 2002-165448 has disclosed a two-way DC-DC converter in which two-way type DC-AC transformation sections are provided on both sides of a transformer. Especially, a secondary DC-AC transformation section has a configuration in which a chalk coil operating as a smoothing coil is used as a chalk coil for a chopper-circuit type inverter using a choke coil at forward power transmission (step-down power transmission from a first DC terminal to a second DC terminal), and a switching and rectifying section between the chalk coil and a secondary coil of the transformer functions as a rectifier at forward-power transmission and is used as a chopper circuit at reverse-power transmission (step-up power transmission from the second DC terminal to the first DC terminal).

[0005] However, there has been a problem that the configuration in which a DC step-up circuit and a DC step-down circuit are disposed in parallel with each other between two DC power supply systems has a large scale circuit, and, at simultaneous operation, enough performance cannot be obtained due to, for example, voltage losses in the circuit.

[0006] Moreover, in the two-way DC-DC converter as disclosed in the above publication, since a switching element in the DC-AC transformation section executes ON-OFF control of a large current, and the current passes through an unsaturated range of the switching element when the large current becomes a zero current by OFF control of the switching element, an operation like an analog operation is actually is executed to cause large switching losses.

[0007] Furthermore, while driving in full synchronization between the primary DC-AC transformation section and the secondary DC-AC transformation section, there is a possibility that a large current might flow on the switching element when a current by one of the DC-AC transformation section flows and ON control of the other DC-AC transformation section is executed.

[0008] The object of the present invention is to solve the above problems, and to provide a two-way DC-DC converter in which switching losses can be reduced; there can be eliminated a possibility that a large current might flow on a switching element at ON-OFF control; and efficient two-way exchange of electric power between DC power supply systems can be realized by a simple control system.

[0009] In order to accomplish the objection, a first aspect of the present invention is a two-wayDC-DC converter comprising : a terminal for a low-voltage side; a terminal for a high-voltage side; a transformer including a winding wire for the low-voltage side and a winding wire for the high-voltage side; a switching section for the low-voltage side inserted between the terminal for the low-voltage side and the winding wire for the low-voltage side; a switching section for the high-voltage side inserted between the terminal for the high-voltage side and the winding wire for the high-voltage side; a rectifying element for the low-voltage side connected in parallel with switching elements in the switching section for the low-voltage side; a rectifying element for the high-voltage side connected in parallel with switching elements in the switching section for the high-voltage side; and a control circuit which controls switching elements in the switching section for the low-voltage side and switching elements in the switching section for the high-voltage side, wherein an LC resonant circuit is provided between the winding wire for the high-voltage side and the switching section for the higher voltage side, or between the winding wire for the low-voltage side and the switching section for the lower voltage side.

[0010] A second aspect of the present invention is the two-way DC-DC converter, wherein the LC resonant circuit is provided between the winding wire for the high-voltage side and the switching section for the higher voltage side.

[0011] A third aspect of the present invention is the two-way DC-DC converter, wherein both of the switching section for the lower voltage side and the switching section for the higher voltage side have a configuration in which four switching elements are bridged.

[0012] According to a first aspect of the present invention, a wave form of a current by switching can be changed into a sinusoidal one by an LC resonant circuit. Thereby, OFF timing of a switching element can be set in the vicinity of a zero crossing point of a current value. Accordingly, switching in the vicinity of the zero crossing point of the current value canbe realized to cause remarkable reduction of switching losses.

[0013] Furthermore, a control system with a simple configuration can be realized because a primary DC-AC transformation section and a secondary DC-AC transformation section can be controlled by the same drive signal. At this time, a conversion efficiency can be improved, because a larger dead time of switching elements, which prevents shortings of switching elements, or a shorter driving period of a switching element is not required. Here, the shortings is caused, for example, by transmission delay in a transformer.

[0014] Moreover, according to a second aspect of the present invention, less losses in a LC resonant circuit can be caused by providing the circuit on the higher voltage side, on which a smaller current flows, in comparison with those of a LC resonant circuit which is provided on the lower voltage side.

[0015] Furthermore, according to a third aspect of the present invention, a simple configuration of a transformer can be realized because both of a switching element for the low-voltage side and a switching element for the high-voltage side form a bridge-type single-phase inverter which is connected to the transformer.

BRIEF DESCRIPTION OF THE DRAWINGS

[0016]

Fig. 1 is a circuit diagram showing one embodiment of a two-way DC-DC converter according to the present invention;

Figs. 2A-2D are views explaining differences in conversion operations by the two-way DC-DC converter between the embodiment of the invention and a previous technology;

Figs. 3A-3D are views explaining differences in operations in full synchronization by the two-way DC-DC converter between the embodiment of the invention and a previous technology; and

Fig. 4 is a circuit diagram showing one application example of the present invention.

[0017] Hereinafter, thepresentinventionwillbeexplainedindetail, referring to drawings. Fig. 1 is a circuit diagram showing one embodiment of a two-way DC-DC converter according to the present invention. The two-way DC-DC converter according to the present embodiment realizes two-way exchange of electric power between a DC power supply connected to terminals 1-1, 1-2 for a low-voltage side and terminals 2-1, 2-2 for a high-voltage side through a transformer 3. Hereinafter, the side of the terminals 1-1, 1-2 for a low-voltage side and that of the terminals 2-1, 2-2 for a high-voltage side will be sometimes called as a primary side, and a secondary side, respectively.

[0018] The transformer 3 comprises awindingwire 3-1 for a low-voltage side and a winding wire 3-2 for a high-voltage side. A step-up voltage ratio of the two-way DC-DC converter is defined by a turns ratio between the winding wire 3-1 for the low-voltage side and the winding wire 3-2 for the high-voltage side. A switching section 4 for the low-voltage side is inserted between the terminals 1-1, 1-2 for the low-voltage side, and the winding wire 3-1 for the low-voltage side, and a switching section 5 for the high-voltage side is inserted between the terminals 2-1, 2-2 for the high-voltage side and the winding wire 3-2 for the high-voltage side.

[0019] The switching section 4 for the lower voltage side has a configuration inwhich, four switching elements (hereinafter, called as FETs) , such a FET, 4-1 through 4-4 are bridged, and the switching section 5 for the higher voltage side has a configuration in which, four FETs 5-1 through 5-4 are bridged.

[0020] Rectifying elements such as a diode are connected in parallel with each FET 4-1 through 4-4 and each FET 5-1 through 5-4. The rectifying elements may be a parasitic diode of FETs, or a joint diode which is separately connected. The switching section 4 for the lower voltage side and the switching section 5 for the higher voltage side could be considered to be a switching and rectifying section, respectively.

[0021] An LC resonant circuit 6 is inserted between the terminals 2-1, 2-2 for the high-voltage side and the winding wire 3-2 for the high-voltage side. Though the LC resonant circuit 6 is a feature of the present invention, the details will be described later.

[0022] Switching control of FETs 4-1 through 4-4 in the switching section 4 for the lower voltage side and FETs 5-1 through 5-4 in the switching section 5 for the higher voltage side is executed by a control circuit (not shown) comprising a CPU and the like. Here, capacitors 7, 8 connected to the primary side and the secondary side, respectively, are a capacitor for output smoothing.

[0023] Then, schematic explanation of operations in Fig. 1 will be made. In the first place, when electric power is supplied from the primary side (the left side in the drawing) to the secondary side (the right side in the drawing) , alternate ON - OFF control between a pair of FET 4-1 and FET 4-4, and a pair of FET 4-2 and FET 4-3 in the switching section 4 for the lower voltage side is executed. A current according to the ON-OFF control flows on the winding wire 3-1 for the low-voltage side in the transformer 3.

[0024] A current induced on the winding wire 3-2 for the high-voltage side is input to the switching section 5 for the higher voltage side through the LC resonant circuit 6, and is smoothed in a smoothing capacitor after rectification by rectifying elements connected in parallel with FET 5-1 through FET 5-4. At this time, the current flowing on the primary side and on the secondary side is changed to a current with a sinusoidal wave form by the existence of the LC resonant circuit 6.

[0025] Though operations for a case in which electric power is supplied from the primary side to the secondary side have been described above, similar operations are applied to a case in which electric power is supplied from the secondary side to the primary side. Moreover, the primary side and the secondary side can be driven in complete synchronization, that is, by the same drive signal. In this case, power exchange between the primary side and the secondary side is executed according to relative differences in the voltage between both sides.

[0026] Figs. 2A-2D are views showing differences in operations between the present invention and a previous technology. Though operations for a case in which electric power is supplied from the primary side to the secondary side will be explained, similar operations are applied to a case in which electric power is supplied from the secondary side to the primary side.

[0027] Figs. 2A, 2C show diagrams of circuits according to the embodiment of the present invention and a previous technology, respectively. The circuits are excerpted in part necessary for explanation of differences in operations, by which electric power is supplied from the primary side to the secondary side in two-way DC-DC converters, between the embodiment of the present invention and the previous technology. Figs. 2B, 2D show current wave forms at Point A in Fig. 2A and Point B in Fig. 2C, respectively.

[0028] In the previous two-way DC-DC converter (Fig. 2C) , a current output through the winding wire 3-1 for the low-voltage side and the winding wire 3-2 for the high-voltage side in the transformer 3 is changed by alternate ON - OFF control between a pair of FET 4-1 and FET 4-4, and a pair of FET 4-2 and FET 4-3 in the switching section 4 for the lower voltage side to a current with a square-wave form, as shown in Fig. 2D. That is, a large current flows before OFF control of FET is executed, but, after the OFF control, the large current is changed into a zero current. At this time, large losses are caused because the current passes through an unsaturated range of FET.

[0029] On the other hand, in the two-way DC-DC converter (Fig. 2A) according to the embodiment of the present invention, a current output through the winding wire 3-1 for the low-voltage side and the winding wire 3-2 for the high-voltage side in the transformer 3 is changed by alternate ON - OFF control between a pair of FET 4-1 and FET 4-4, and a pair of FET 4-2 and FET 4-3 in the switching section 4 for the lower voltage side to a current with a sinusoidal wave form, as shown in Fig. 2B. This is caused by the existence of the LC resonant circuit 6.

[0030] Thereby, OFF timing of FET can be set in the vicinity of a zero crossing point at which the value of the current becomes approximately zero. Accordingly, switching of FET can be executed in the vicinity of the zero crossing point of the current value to cause remarkable reduction in the switching losses.

[0031] The present invention is also effective for a case in which the primary side and the secondary side is driven in full synchronization, that is, by the same driving signal. Hereinafter, this will be explained. Figs. 3A, 3C show diagrams of circuits according to the embodiment of the present invention and a previous technology, respectively. The circuits are excerpted in part necessary for explanation of differences in operations, by which the primary side and the secondary side in the two-way DC-DC converters are driven in full synchronization. Noting switching on the primary side, Figs. 3B, 3D show current wave forms of a primary-side current and a secondary-side current, respectively.

[0032] In the previous two-way DC-DC converter (Fig. 3C), the primary-side current with a square-wave form shown by dotted and dashed lines in Fig. 3D flows on the primary side (the winding wire 3-1 for the low-voltage side in the transformer 3) by alternate ON - OFF control between a pair of FET 4-1 and FET 4-4, and a pair of FET 4-2 and FET 4-3 in the switching section 4 for the lower voltage side.

[0033] By the primary-side current, the secondary-side current with a square-wave form shown by solid lines in Fig. 3D flows on the secondary side (the winding wire 3-2 for the high-voltage side in the transformer 3) , but the secondary-side current has slight delay behind the primary-side current, for example, due to delay in the transformer 3.

[0034] When the primary side and the secondary side are driven in full synchronization under such a condition, ON-control of the secondary side is caused (a circled part in Fig. 3D) , if the delay of the secondary side current exceeds dead time and a large current flows by ON-control of the primary side. Thereby, the large current by ON-control of the secondary side is further superimposed onto the large current by ON-control of the primary side.

[0035] In order to prevent the above superposition, a shorter driving period of FET on the secondary side or longer dead time is required for no ON-control of the secondary side while a large current by ON-control of the primary side flows. Thereby, the above measure becomes a big factor causing reduction in the conversion efficiency.

[0036] On the other hand, in the two-way DC-DC converter (Fig. 3A) according to the embodiment of the present invention, the primary-side current with a sinusoidal wave form shown by dotted and dashed lines in Fig. 3B flows on the primary side by alternate ON - OFF control between a pair of FET 4-1 and FET 4-4, and a pair of FET 4-2 and FET 4-3 in the switching section 4 for the lower voltage side.

[0037] By the primary-side current, the secondary-side current with a sinusoidal wave form shown by solid lines in Fig. 3B flows on the secondary side, but the secondary-side current has slight delay behind the primary-side current, for example, due to delay in the transformer 3.

[0038] Here, when the secondary side and the primary side are driven in full synchronization, ON-control of the secondary side is caused at a zero crossing point of the current by ON-control of the primary side (a circled part in Fig. 3B) , even if the delay of the secondary side current exceed dead time. Thereby, the large current does not flow because both the large current by ON-control of the primary side and the current by ON-control of the secondary side are small.

[0039] Fig. 4 is a circuit diagram showing one application example of the present invention, in which two-way exchange of electric power between a DC power supply including a generator 10 and a battery 12 is executed, and the generator 10 is, for example, a three-phase multipolar magnet generator. When an engine is started, the switching section for the lower voltage side in the two-way DC-DC converter 11 is converted, the DC voltage of the battery 12, which has been step-upped by the above driving, is applied to the drive inverter (rectifier circuit) 13. By the drive inverter 13, the applied DC voltage is converted into a three-phase AC voltage, and is applied to the generator 10. Thereby, the generator 10 is started as an engine starting electric motor.

[0040] When the engine is started, the generator 10 is driven by the engine to stop switching operation of the drive inverter 13. The output of the generator 10 is rectified in the rectifier circuit (drive inverter) 13, is regulated in a regulator 14, and is converted in an inverter 15 into AC power of a predetermined frequency.

[0041] If a switching section 5-3 for the higher voltage side in the two-way DC-DC converter 11 is driven when the voltage of the battery 12 is reduced, the output voltage of the rectifier circuit 13 is reduced in the two-way DC-DC converter 11. Thereby, the battery 12 can be charged by the reduced voltage.

[0042] The switching section for the lower voltage side and the switching section for the higher voltage side of the two-way DC-DC converter 11 can be also driven in full synchronization with each other, when the generator 10 is driven by the engine. Thus, automatic power exchange between the side of the rectifier circuit (drive inverter) 13 and that of the battery 12 can be executed according to relative differences in the voltage between the primary side and the secondary side caused by the turns ratio of the transformer.

[0043] Though the embodiments have been explained as described above, various kinds of changes andmodifications couldbemade . For example, the LC resonant circuit can be provided in the primary side. In this case, the LC resonant circuit may be inserted between the switching section for the lower voltage side and the winding wire for the low-voltage side.

[0044] The present invention can be used for a case in which two-way exchange of electric power not only between the batteries or between the DC power supply comprising the engine generator and the batteries, but also between DC power supply systems such as a common generator, a solar light generating system, a wind power generation system, and a fuel cell system is executed. For example, two-way exchange of electric power between an electrical power system for running and a safety electrical system can be realized for example, for a hybrid electric vehicle.

[0045] As the detailed explanation has been made above, a wave form of a current by switching can be changed into a sinusoidal one by an LC resonant circuit, according to the presentinvention. Thereby, OFF timing of a switching element can be set in the vicinity of a zero crossing point of a current value. Accordingly, switching in the vicinity of the zero crossing point of the current value can be realized to cause remarkable reduction of switching losses.

[0046] Moreover, a switching section for the lower voltage side and a switching section for the higher voltage side can be controlled by the same drive signal. At this time, a conversion efficiency can be improved, because a larger dead time or a shorter driving period of a switching element is not required in order to control flowing of a large current, which is caused, for example, by transmission delay in a transformer, on the switching element.

[0047] Furthermore, the switching section for the lower voltage side and the switching section for the higher voltage side can be controlled by the same drive signal to cause no requirements for changing conversion direction at driving. Thereby, a load to a control system can be reduced.

Claims

1. A two-way DC-DC converter comprising: a terminal (1-1, 1-2) for a low-voltage side; a terminal (2-1, 2-2) for a high-voltage side; a transformer (3) including a winding wire (3-1) for the low-voltage side and a winding wire (3-2) for the high-voltage side; a switching section (4) for the low-voltage side inserted between the terminal (1-1, 1-2) for the low-voltage side and the winding wire (3-1) for the low-voltage side; a switching section (5) for the high-voltage side inserted between the terminal (2-1, 2-2) for the high-voltage side and the winding wire (3-2) for the high-voltage side; a rectifying element for the low-voltage side connected in parallel with switching elements (4-1 through 4-4) in the switching section (4) for the low-voltage side; a rectifying element for the high-voltage side connected in parallel with switching elements (5-1 through 5-4) in the switching section (5) for the high-voltage side; and a control circuit which controls switching elements (4-1 through 4-4) in the switching section (4) for the low-voltage side and switching elements (5-1 through 5-4) in the switching section (5) for the high-voltage side, wherein

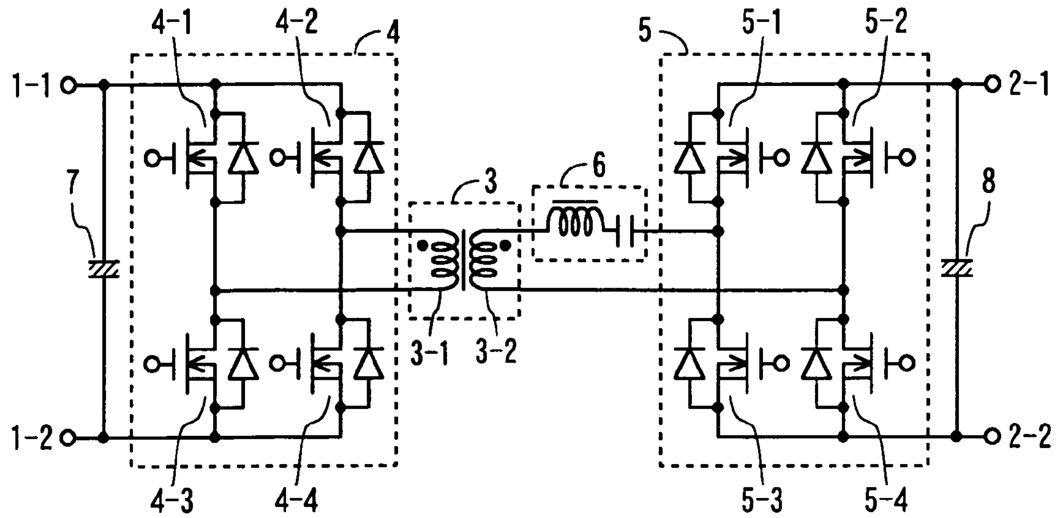
   an LC resonant circuit (6) is provided between the winding wire (3-2) for the high-voltage side and the switching section (5) for the higher voltage side, or between the winding wire (3-1) for the low-voltage side and the switching section (4) for the lower voltage side.

2. The two-way DC-DC converter according to claim 1, wherein the LC resonant circuit (6) is provided between the winding wire (3-2) for the high-voltage side and the switching section (5) for the higher voltage side.

3. The two-way DC-DC converter according to claim 1, wherein both of the switching section (4) for the lower voltage side and the switching section (5) for

the higher voltage side have a configuration in which four switching elements (4-1 through 4-4, 5-1 through 5-5) are bridged.

Fig. 1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5
5-1
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1-1
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7
3
6
8
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2-2
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5-4

Fig. 3A

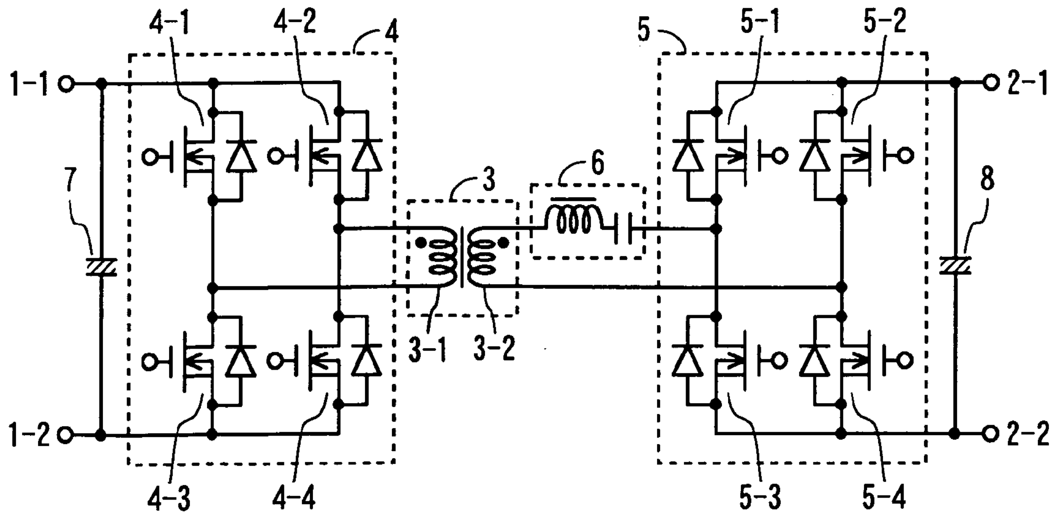
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Fig. 2A

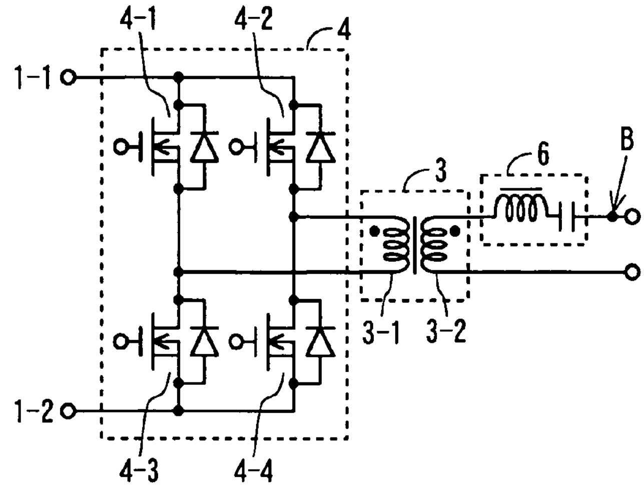


Fig. 2B

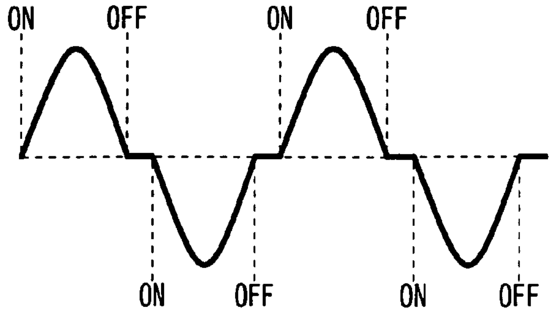


Fig. 2C

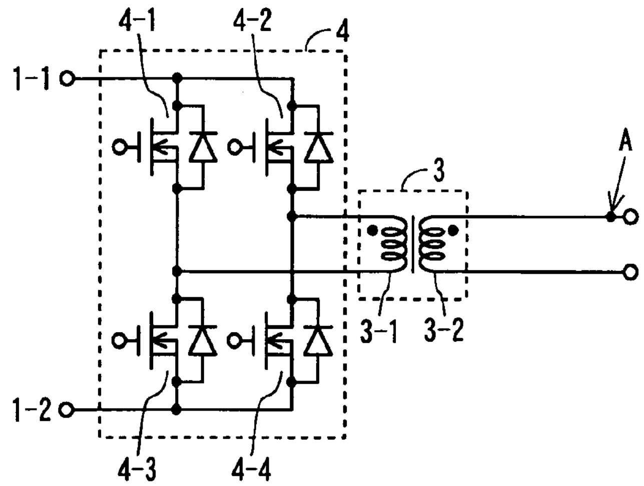


Fig. 2D

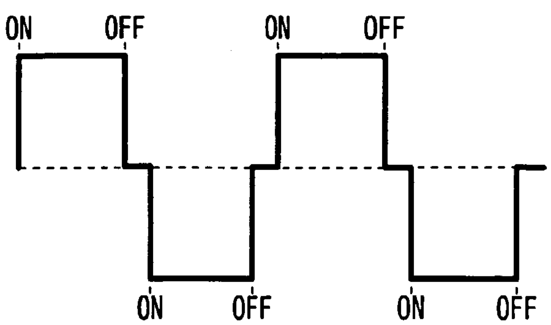


Fig. 3B

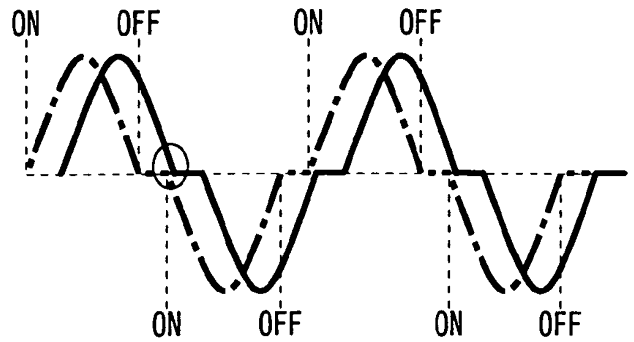


Fig. 3C

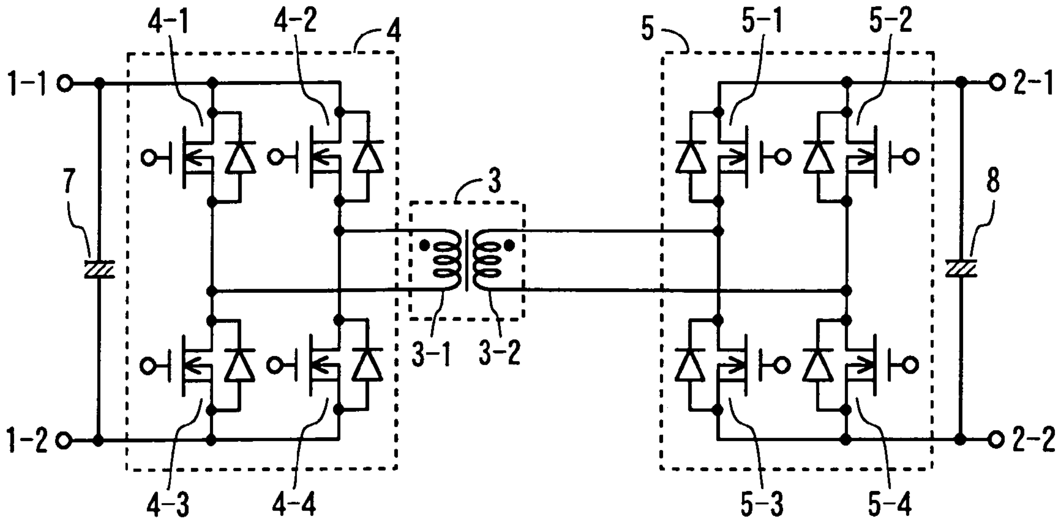
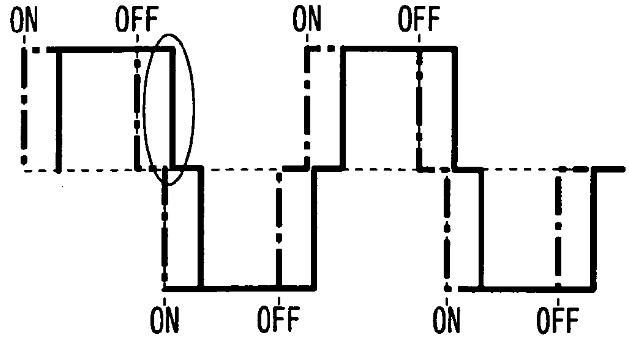


Fig. 3D



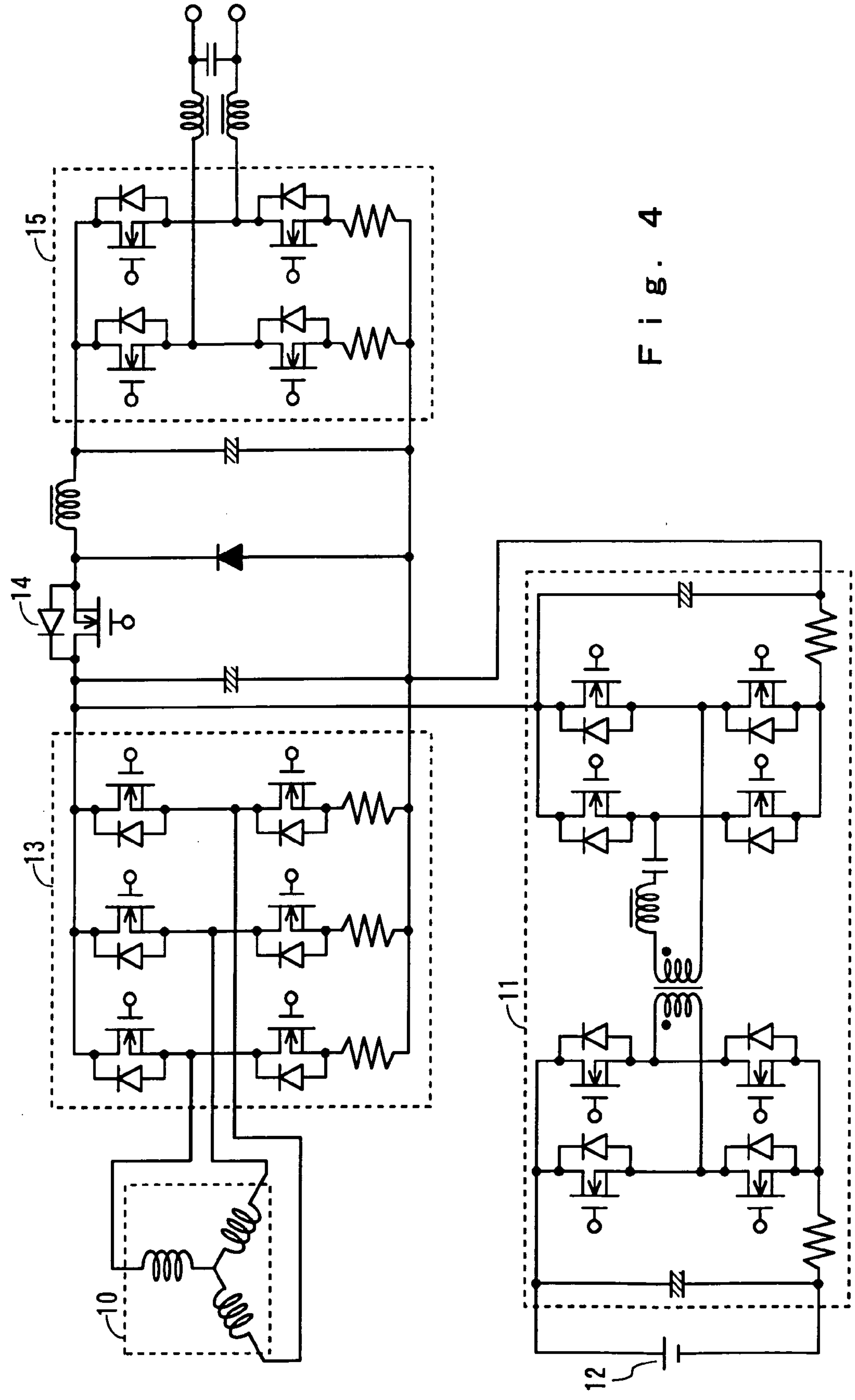


Fig. 4

Espacenet

Bibliographic data: CN103986355 (A) — 2014-08-13

Low-voltage double-circuit MPPT high-frequency isolated type grid-connected inverter

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- **cooperative:**

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Abstract of CN103986355 (A)

The invention discloses a low-voltage double-circuit MPPT high-frequency isolated type grid-connected inverter comprising first primary direct-current electric energy and second primary direct-current electric energy. The first primary direct-current electric energy and the second primary direct-current electric energy are output to a first step-down circuit and a second step-down circuit respectively. The output end of the first step-down circuit and the output end of the second step-down circuit are both connected with a high-frequency full-bridge inversion circuit. The high-frequency full-bridge inversion circuit is connected with a rectifying circuit. The rectifying circuit is connected with a full-bridge power frequency inversion circuit. The full-bridge power frequency inversion circuit is connected with a filtering circuit. The output end of the filtering circuit is connected to a power grid. According to the technical scheme, at least two series-connected battery packs can be connected to one path of direct-current input voltage, and therefore the battery packs can be arranged more flexibly; the maximum power tracing function can be achieved through two paths of direct-current input; electrical isolation is conducted through a high-frequency transformer, so that it is guaranteed that a system is safe and reliable, and the negative electrode or the positive electrode of the two paths of direct-current input can be grounded.

Notice

DESCRIPTION CN103986355A

10 A low-voltage dual-channel MPPT high-frequency isolation grid-connected inverter

[0001]

14 Technical field

[0002]

18 The invention belongs to the technical field of power supplies, and specifically relates to a low-voltage dual-channel MPPT high-frequency isolation type grid-connected inverter.

[0003]

23 Background technique

[0004]

27 In some small and medium-sized photovoltaic grid-connected power generation systems, two roofs with different sides are often encountered to install solar panels. In this case, if a single-channel maximum power tracking inverter is used, two inverters are required on the side. There are two maximum power tracking functions on each inverter, and one inverter on the side can meet the requirements.

31 The general area of the two roofs is different. Some roofs are equipped with only two battery panels, and some roofs may have more than a dozen battery panels. In this case, the input voltage range of at least one inverter is very low. At the same time, in order to achieve electrical isolation and can be used with any kind of components, a low-voltage dual maximum power tracking (MPPT) high-frequency isolated grid-connected inverter was developed based on this.

[0005]

39 Summary of the invention

[0006]

43 The purpose of the present invention is to overcome the problems existing in the prior art and provide a low-voltage dual-channel MPPT high-frequency isolation type grid-connected inverter.

[0007]

48 In order to achieve the above technical objectives and achieve the above technical effects, the present invention is achieved through the following technical solutions:

[0008]

53 A low-voltage dual-channel MPPT high-frequency isolation grid-connected inverter, including a first primary DC power and a second primary DC power, the first primary DC power and the second primary DC power are respectively output to the first drop The output ends of the first step-down circuit and the second step-down circuit are both connected to a high-frequency full-bridge inverter circuit, and the high-frequency full-bridge inverter circuit is connected to the rectifier circuit. The rectifier circuit is connected to a full-bridge power frequency inverter circuit, the full-bridge power frequency inverter circuit is connected to the filter circuit, and the output end of the filter circuit is connected to the power grid.

[0009]

63 Further, the second step-down circuit is also connected to a sampling circuit, an output terminal of the sampling circuit is connected to a control module, and the control module is connected to a driving circuit. The step-down circuit, the second step-down circuit, the high-frequency full-bridge inverter circuit and the full-bridge power frequency inverter circuit are connected, and the control module is also connected to a display and communication module.

[0010]

71 The beneficial effects of the present invention:

[0011]

75 The technical solution of the present invention has a wide range of DC input voltage and the lowest voltage can reach 48V, and one channel can be connected to two series-connected battery components at the lowest. The configuration of battery components is more flexible; the two channels of DC input can achieve the maximum power tracking function separately. Different roofs can be installed; high-frequency transformers are used for electrical isolation to ensure the safety and reliability of the system. At the same time, the negative or positive

grounding of the two DC inputs can be realized.

[0012]

84 Description of the drawings

[0013]

88 Figure 1 is the overall control block diagram of the present invention;

[0014]

92 Figure 2 is a schematic diagram of the overall control of the present invention.

[0015]

96 Detailed ways

[0016]

100 Hereinafter, the present invention will be described in detail with reference to the drawings and in conjunction with the embodiments.

[0017]

105 1 and 2, a low-voltage dual-channel MPPT high-frequency isolation grid-connected inverter includes a first primary DC power and a second primary DC power, the first primary DC power and the second primary DC power The primary DC power is respectively output to the first step-down circuit and the second step-down circuit. The output ends of the first step-down circuit and the second step-down circuit are both connected to a high-frequency full-bridge inverter circuit. The variable circuit is connected with the rectifier circuit, the rectifier circuit is connected with the full-bridge power frequency inverter circuit, the full bridge power frequency inverter circuit is connected with the filter circuit, and the output end of the filter circuit is connected to the power grid.

[0018]

116 Further, the second step-down circuit is also connected to a sampling circuit, an output terminal of the sampling circuit is connected to a control module, and the control module is connected to a driving circuit. The step-down circuit, the second step-down circuit, the high-frequency full-bridge inverter circuit and the full-bridge power frequency inverter circuit are connected, and the control module is also connected to a display and communication module.

[0019]

124 Principle of the present invention:

[0020]

128 The control core of the present invention adopts TMS320LF2407 chip; the two-way chopper circuit of the front stage is controlled by PWM10 and PWM12 of the main control chip; the full-bridge high frequency inverter is controlled by PWM9 and PWM11; the latter stage uses a dedicated control chip UC2854 for power frequency inversion Change; Two-way chopper circuit adopts current loop control mode.

[0021]

135 The foregoing descriptions are only preferred embodiments of the present invention and are not used to limit the present invention. For those skilled in the art, the present invention can have various modifications and changes.

138 Any modification, equivalent replacement, improvement, etc. made within the spirit and principle of the present invention should be included in the protection scope of the present invention.

Notice

CLAIMS CN103986355A

1.

13 A low-voltage dual-channel MPPT high-frequency isolation grid-connected inverter, comprising a first primary DC power and a second primary DC power, characterized in that the first primary DC power and the second primary DC power are output separately To the first step-down circuit and the second step-down circuit, the output ends of the first step-down circuit and the second step-down circuit are both connected to a high-frequency full-bridge inverter circuit, and the high-frequency full-bridge inverter circuit is connected to the rectifier circuit. Connected, the rectifier circuit is connected to a full-bridge power frequency inverter circuit, the full-bridge power frequency inverter circuit is connected to a filter circuit, and the output end of the filter circuit is connected to the power grid.

2.

24 The low-voltage dual-channel MPPT high-frequency isolation grid-connected inverter according to claim **1**, wherein the second step-down circuit is also connected to a sampling circuit, and the output terminal of the sampling circuit is connected to the control module, The control module is connected to the drive circuit, and the output end of the drive circuit is also connected to the first step-down circuit, the second step-down circuit, the high-frequency full-bridge inverter circuit, and the full-bridge power frequency inverter, respectively. The variable circuit is connected, and the control module is also connected with the display and communication module.

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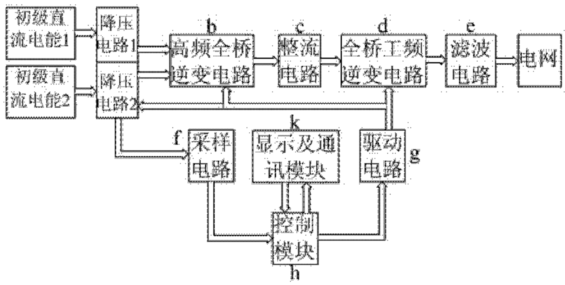
权利要求书1页　说明书2页　附图1页

(54)发明名称

一种低压双路MPPT高频隔离型并网逆变器

(57)摘要

本发明公开了一种低压双路MPPT高频隔离型并网逆变器，包括第一初级直流电能和第二初级直流电能，所述第一初级直流电能和所述第二初级直流电能分别输出到第一降压电路和第二降压电路，所述第一降压电路和所述第二降压电路的输出端都与高频全桥逆变电路连接，所述高频全桥逆变电路与整流电路连接，所述整流电路与全桥工频逆变电路连接，所述全桥工频逆变电路与滤波电路连接，所述滤波电路的输出端连接到电网。本发明技术方案的直流输入电压一路最低可以接入两块串连电池组件，配置电池组件更加灵活；两路直流输入可以单独实现最大功率跟踪功能；采用高频变压器进行电气隔离，确保系统安全可靠，同时可以实现两路直流输入的负极或正极接地。



CN 103986355 A

1. 一种低压双路 MPPT 高频隔离型并网逆变器,包括第一初级直流电能和第二初级直流电能,其特征在于,所述第一初级直流电能和所述第二初级直流电能分别输出到第一降压电路和第二降压电路,所述第一降压电路和所述第二降压电路的输出端都与高频全桥逆变电路连接,所述高频全桥逆变电路与整流电路连接,所述整流电路与全桥工频逆变电路连接,所述全桥工频逆变电路与滤波电路连接,所述滤波电路的输出端连接到电网。

2. 根据权利要求 1 所述的低压双路 MPPT 高频隔离型并网逆变器,其特征在于,所述第二降压电路还与采样电路连接,所述采样电路的输出端与控制模块连接,所述控制模块与驱动电路连接,所述驱动电路的输出端还分别与第一所述降压电路,所述第二降压电路,所述高频全桥逆变电路和所述全桥工频逆变电路连接,所述控制模块还与显示及通讯模块相互连接。

一种低压双路 MPPT 高频隔离型并网逆变器

技术领域

[0001] 本发明属于电源技术领域，具体涉及一种低压双路 MPPT 高频隔离型并网逆变器。

背景技术

[0002] 在一些中小型光伏并网发电系统中，经常遇到两个不同侧面的屋顶来安装太阳能电池板，在这种情况下如果使用单路最大功率跟踪的逆变器，侧需要两台，如果一台逆变器上有两路最大功率跟踪功能，侧一台逆变器就能满足要求。而两个屋面一般面积各不相同，有的最小只装有两块电池板，有的屋面可能装有十几块电池板，在这种情况下，逆变器至少一路输入电压范围就非常低，同时为了实现电气隔离并且可以与任意种组件配套使用，基于此开发了低压双路最大功率跟踪（MPPT）高频隔离型并网逆变器。

发明内容

[0003] 本发明的目的在于克服现有技术存在的问题，提供一种低压双路 MPPT 高频隔离型并网逆变器。

[0004] 为实现上述技术目的，达到上述技术效果，本发明通过以下技术方案实现：

一种低压双路 MPPT 高频隔离型并网逆变器，包括第一初级直流电能和第二初级直流电能，所述第一初级直流电能和所述第二初级直流电能分别输出到第一降压电路和第二降压电路，所述第一降压电路和所述第二降压电路的输出端都与高频全桥逆变电路连接，所述高频全桥逆变电路与整流电路连接，所述整流电路与全桥工频逆变电路连接，所述全桥工频逆变电路与滤波电路连接，所述滤波电路的输出端连接到电网。

[0005] 进一步的，所述第二降压电路还与采样电路连接，所述采样电路的输出端与控制模块连接，所述控制模块与驱动电路连接，所述驱动电路的输出端还分别与第一所述降压电路，所述第二降压电路，所述高频全桥逆变电路和所述全桥工频逆变电路连接，所述控制模块还与显示及通讯模块相互连接。

[0006] 本发明的有益效果：

本发明技术方案的直流输入电压范围宽泛最低电压可以达到 48 伏，一路最低可以接入两块串连电池组件，配置电池组件更加灵活；两路直流输入可以单独实现最大功率跟踪功能，两路组件可以安装不同的屋面；采用高频变压器进行电气隔离，确保系统安全可靠，同时可以实现两路直流输入的负极或正极接地。

附图说明

[0007] 图 1 是本发明的整体控制框图；

图 2 是本发明的整体控制示意图。

具体实施方式

[0008] 下面将参考附图并结合实施例，来详细说明本发明。

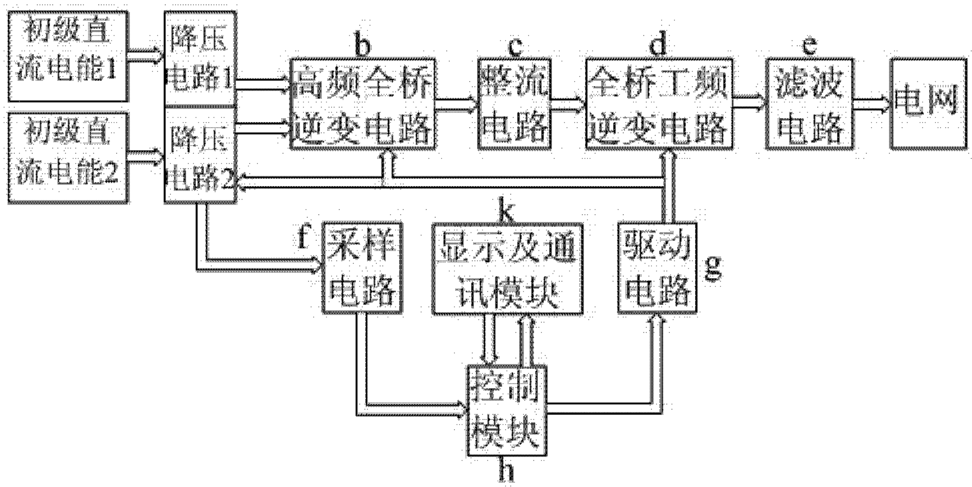
[0009]　参照图 1 和图 2 所示，一种低压双路 MPPT 高频隔离型并网逆变器，包括第一初级直流电能和第二初级直流电能，所述第一初级直流电能和所述第二初级直流电能分别输出到第一降压电路和第二降压电路，所述第一降压电路和所述第二降压电路的输出端都与高频全桥逆变电路连接，所述高频全桥逆变电路与整流电路连接，所述整流电路与全桥工频逆变电路连接，所述全桥工频逆变电路与滤波电路连接，所述滤波电路的输出端连接到电网。

[0010]　进一步的，所述第二降压电路还与采样电路连接，所述采样电路的输出端与控制模块连接，所述控制模块与驱动电路连接，所述驱动电路的输出端还分别与第一所述降压电路，所述第二降压电路，所述高频全桥逆变电路和所述全桥工频逆变电路连接，所述控制模块还与显示及通讯模块相互连接。

[0011]　本发明的原理：

本发明控制核心采用 TMS320LF2407 芯片；前级两路斩波电路有主控制芯片的 PWM10、PWM12 来控制；全桥高频逆变有 PWM9 和 PWM11 来控制；后级采用专用控制芯片 UC2854 进行工频逆变；两路斩波电路采用电流环控制方式。

[0012]　以上所述仅为本发明的优选实施例而已，并不用于限制本发明，对于本领域的技术人员来说，本发明可以有各种更改和变化。凡在本发明的精神和原则之内，所作的任何修改、等同替换、改进等，均应包含在本发明的保护范围之内。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初级直流电能2
降压电路1
降压电路2
b
高频全桥逆变电路
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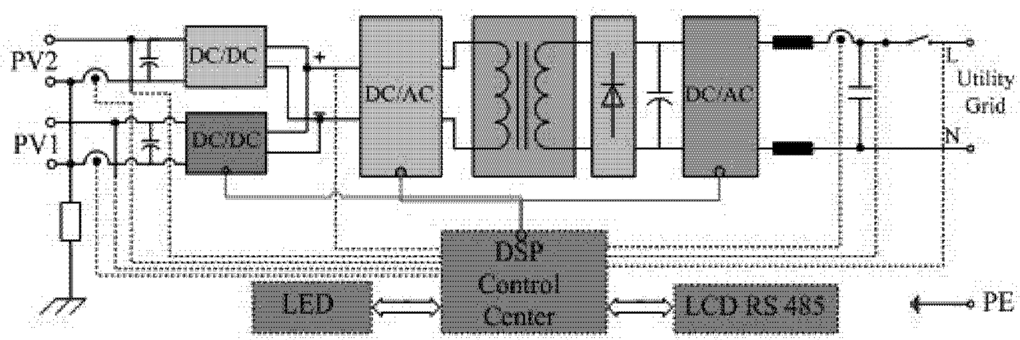
d
全桥工频逆变电路
e
滤波电路
电网
f
采样电路
k
显示及通讯模块
驱动电路
g
控制模块
h

图 1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PV1
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DC/DC
DC/AC
DC/AC
L
Utility
Grid
N
DSP
Control
Center
LED
LCD RS 485
PE

图 2