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

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
30 September 2010 (30.09.2010)

PCT

(10) International Publication Number
WO 2010/111433 A2

(51) International Patent Classification:
H02M 7/48 (2007.01) *H02M 7/12* (2006.01)

(21) International Application Number:
PCT/US2010/028556

(22) International Filing Date:
24 March 2010 (24.03.2010)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
61/163,214 25 March 2009 (25.03.2009) US

(71) Applicant *(for all designated States except US)*: **POWERGETICS, INC.** [US/US]; 3150 18th Street, Suite 414, San Francisco, CA 94110 (US).

(72) Inventor; and
(75) Inventor/Applicant *(for US only)*: **SMITH, Lynn, B.** [US/US]; 351 Megan Blvd., Ozark, AL 36360-6166 (US).

(74) Agents: **KIM, Elaine A.** et al.; Wilson Sonsini Goodrich & Rosati, 650 Page Mill Road, Palo Alto, CA 94304-1050 (US).

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

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

Published:

— *without international search report and to be republished upon receipt of that report (Rule 48.2(g))*

WO 2010/111433 A2

(54) Title: BIDIRECTIONAL ENERGY CONVERTER

(57) Abstract: The invention provides a bidirectional converter that operates under an AC generation mode or a charge mode. The bidirectional converter may be a single component or circuit, which may include a DC-DC conversion stage using a unique "Smith 2 Stage conversion" technique and a DC-AC conversion stage or AC-DC conversion stage using a switchable filter depending on the mode. During the charge mode, the converter may be able to control the voltage and current of the DC output using a software algorithm, to match the battery being charged, or the DC receiver. This may enable the converter to control the nature of the DC output so it can be adapted to any energy storage technology. The controllable output voltage and synchronizable frequency may allow the converter to be used in series combinations to achieve a variety of high voltage outputs from simpler

BIDIRECTIONAL ENERGY CONVERTER

CROSS-REFERENCE

[0001] This application claims the benefit of U.S. Provisional Application No. 61/163,214 filed March 25, 2009, which application is incorporated herein by reference in its entirety.

BACKGROUND OF THE INVENTION

[0002] Traditional energy storage or conversion systems have utilized converters to transfer energy from DC to AC, or vice versa. For instance, an inverter may be utilized to convert energy from DC to AC, and a rectifier may be used to convert energy from AC to DC. Systems have been developed to both charge and discharge an energy storage system. Traditionally, separate inverter and rectifier circuits are utilized for each type of energy conversion. Various energy conversion configurations have been developed in order to allow such functions. See, e.g., U.S. Patent No. 6,160,722, U.S. Patent Publication No. 2004/0062059, U.S. Patent No. 6,587,362, U.S. Patent Publication No. 2003/0057919, and U.S. Patent No. 6,750,685, which are hereby incorporated by reference in their entirety. Furthermore, traditional energy conversion systems used as battery chargers are unable to adapt to various energy storage technologies, such that single customized designs are required for a given battery technology.

[0003] A need exists for a bidirectional converter that enables bidirectional conversion between AC and DC within the same component or circuit. A further need exists for an AC to DC converter, which may be used to charge an energy storage device, capable of controlling the DC output to adapt to an energy storage technology.

SUMMARY OF THE INVENTION

[0004] The invention provides systems and methods for bidirectional energy conversion. Various aspects of the invention described herein may be applied to any of the particular applications set forth below or for any other types of circuits or devices. The invention may be applied as a standalone system or method, or as part of an integrated package, such as an energy storage charging or discharging system. It shall be understood that different aspects of the invention can be appreciated individually, collectively, or in combination with each other.

[0005] In accordance with an aspect of the invention, a bidirectional converter may be provided. The bidirectional converter may be formed such that it may function as a DC to AC energy converter and/or an AC to DC energy converter within the same device or component. For example, a circuit may be provided that may function for bidirectional energy conversion. Within the circuit, current may flow in opposite directions, depending on the mode of operation. Thus, the same bidirectional converter may be able to function as an inverter and as a rectifier.

[0006] A bidirectional converter can, under software control, reconfigure itself from an AC generation mode to a charge mode. In an AC generation mode, DC input power from an energy source such as a battery or capacitor may be converted to AC. For instance, the DC input power may be converted to 120 VAC, 50/60 Hz, single phase. In a charge mode, AC may be converted to DC. In one

implementation, 120VAC, 50/60 Hz may be converted to DC under a specified algorithm to recharge the DC power source.

[0007] The bidirectional converter may operate in series, parallel, or series/parallel combinations with other bidirectional converters as a part of an energy storage unit (ESU). The ESU may supply 240VAC, 50/60 Hz, single phase, 208 VAC, 50/60 Hz, 3 phase Wye or 480VAC, 3 phase Wye or Delta connected AC power at various power levels determined by the ESU configuration and number of bidirectional converters. The operation of the converters in series may be advantageous in enabling a unit operating at 120VAC to 138VAC as a building block for another voltage output, such as 240VAC, 208 VAC or 277 VAC up to 480 VAC. Traditional inverters operate at either 120 or 240 VAC and can operate in parallel, but not as a building block to higher voltages.

[0008] The output voltage and current of the bidirectional converter may be controlled very precisely so as to enable precise delivery of power and energy to the desired load or when interconnected to an electric grid to deliver a precise amount of power and energy to the grid. For example this would allow the bidirectional converter to deliver a precise number of watts of power against a given load or a precise amount of energy on command.

[0009] The response time of the bidirectional converter to change from the charge mode to the AC generation mode may be less than one cycle at 60 Hz (16 ms). However, the actual time of mode change may vary, and may depend on the time it takes to detect the circumstances that can trigger the change (loss of AC, etc.). The invention may advantageously provide a design that can convert from being an inverter to being a battery charger. The bidirectional converter may change modes 'on the fly.' The bidirectional converter may also have a programmable battery charger algorithm in charge mode as well as a smooth transition to AC generation mode (including a constant voltage mode). This can be especially useful in energy recapture applications such as automobile regenerative braking, elevator energy recapture, standby power, etc. This may reduce or eliminate duplicative charge vs. power systems and the attendant harmonic and resonance problems that can arise from feedback loops attendant to traditional two part designs.

[0010] In the AC generation mode, the bidirectional converter can be programmed to monitor the AC line and provide power under specified overload or 'spike in usage' conditions.

[0011] The bidirectional converter design may be efficient and reliable. Fault monitoring and reporting software may be part of the control system. Such monitoring and control may provide a sophisticated design for a single converter module in use with others. The bidirectional converter can also be commanded to turn off or isolate from a group of converters. The converter may perform some form of self-check, which may be adopted in the software and hardware control.

[0012] Another feature that can be implemented into the system may be to shift the frequencies (e.g., 100 KHz and 30 KHz) slightly on a constant basis in co-ordination with the other bidirectional converters in the system to minimize or reduce electromagnetic interference (EMI) emissions. A control system may

be coordinating and communicating with the bidirectional converters to operate at desirable frequencies with respect to one another.

[0013] Other goals and advantages of the invention will be further appreciated and understood when considered in conjunction with the following description and accompanying drawings. While the following description may contain specific details describing particular embodiments of the invention, this should not be construed as limitations to the scope of the invention but rather as an exemplification of preferable embodiments. For each aspect of the invention, many variations are possible as suggested herein that are known to those of ordinary skill in the art. A variety of changes and modifications can be made within the scope of the invention without departing from the spirit thereof.

INCORPORATION BY REFERENCE

[0014] All publications, patents, and patent applications mentioned in this specification are herein incorporated by reference to the same extent as if each individual publication, patent, or patent application was specifically and individually indicated to be incorporated by reference.

BRIEF DESCRIPTION OF THE FIGURES

[0015] The novel features of the invention are set forth with particularity in the appended claims. A better understanding of the features and advantages of the present invention will be obtained by reference to the following detailed description that sets forth illustrative embodiments, in which the principles of the invention are utilized, and the accompanying drawings of which:

[0016] FIG. 1 shows a functional block diagram for an AC generation mode.

[0017] FIG. 2 shows a DC-DC converter driver stage.

[0018] FIG. 3 shows an example of a drive waveform for Q1 - Q4.

[0019] FIG. 4 shows a DC-DC converter synchronous rectifier stage.

[0020] FIG. 5 shows an example of a timing relationship between drivers Q1 - Q4 and synchronous rectifiers Q5 - Q8.

[0021] FIG. 6 shows an "H" bridge AC output stage.

[0022] FIG. 7 shows an example of timing relationships for an "H" Bridge output stage.

[0023] FIG. 8 shows a functional block diagram for a charge mode.

[0024] FIG. 9 shows an example of where Q9 – Q11 may reverse roles and serve as a bridge rectifier.

[0025] FIG. 10 shows an example of rectifier timing.

[0026] FIG. 11 shows a DC to DC converter driver stage.

[0027] FIG. 12 shows an example of a timing relationship for Q5, Q6, Q7, and Q8.

[0028] FIG. 13 shows a DC output stage to a battery.

[0029] FIG. 14 shows a functional block diagram for an AC generation mode, in accordance with another embodiment of the invention.

[0030] FIG. 15 shows a DC-DC converter driver stage.

[0031] FIG. 16 shows an example of a drive waveform for Q7, Q8.

[0032] FIG. 17 shows a DC-DC converter synchronous rectifier stage.

[0033] FIG. 18 shows an example of a timing relationship between drivers Q7, Q8 and rectifiers Q5 and Q6.

[0034] FIG. 19 shows an "H" bridge AC output stage.

[0035] FIG. 20 shows an example of timing relationships for an "H" Bridge output stage.

[0036] FIG. 21 shows a functional block diagram for a charge mode.

[0037] FIG. 22 shows an example of where Q1 – Q4 may reverse roles and serve as a bridge rectifier.

[0038] FIG. 23 shows an example of rectifier timing.

[0039] FIG. 24 shows a DC to DC converter driver stage.

[0040] FIG. 25 shows an example of a timing relationship for Q5, Q6, Q9, and Q10.

[0041] FIG. 26 shows a DC output stage to a battery.

DETAILED DESCRIPTION OF THE INVENTION

[0042] While preferred embodiments of the invention have been shown and described herein, it will be obvious to those skilled in the art that such embodiments are provided by way of example only. Numerous variations, changes, and substitutions will now occur to those skilled in the art without departing from the invention. It should be understood that various alternatives to the embodiments of the invention described herein may be employed in practicing the invention.

[0043] The invention provides a bidirectional converter, that may operate in an AC generation mode, where the bidirectional converter may function as an inverter to convert DC to AC. The bidirectional converter may also operate in a charge mode, where the bidirectional converter may function as a rectifier to convert AC to DC. The bidirectional converter may be able to operate in both modes within the same device or component, rather than utilizing two separate circuits or components for each mode. A single circuit may be utilized to form the bidirectional converter. For different modes, the same circuit with the same paths may be operating in forward or reverse. In an AC generation mode, a circuit may be provided with a path to convert DC to AC. In a charge mode, the same circuit may be provided with the same path to convert AC to DC. In some instances, current may flow in different (and/or opposing) directions along the same circuit for a DC to AC mode and an AC to DC mode.

[0044] A bidirectional converter may comprise at least one DC terminal and at least one AC terminal. A DC terminal may function as a DC input when the converter is in AC generation mode, and may function as a DC output when the converter is in charge mode. An AC terminal may function as an AC output when the converter is in AC generation mode, and may function as an AC input when the converter is in charge mode.

[0045] The bidirectional converter may include a DC-DC conversion stage disposed between the DC terminal and the AC terminal. The converter may also include a bridge conversion stage disposed

DOCKET ALARM

Explore Litigation Insights

Docket Alarm provides insights to develop a more informed litigation strategy and the peace of mind of knowing you're on top of things.

Real-Time Litigation Alerts

Keep your litigation team up-to-date with **real-time alerts** and advanced team management tools built for the enterprise, all while greatly reducing PACER spend.

Our comprehensive service means we can handle Federal, State, and Administrative courts across the country.

Advanced Docket Research

With over 230 million records, Docket Alarm's cloud-native docket research platform finds what other services can't. Coverage includes Federal, State, plus PTAB, TTAB, ITC and NLRB decisions, all in one place.

Identify arguments that have been successful in the past with full text, pinpoint searching. Link to case law cited within any court document via Fastcase.

Analytics At Your Fingertips

Learn what happened the last time a particular judge, opposing counsel or company faced cases similar to yours.

Advanced out-of-the-box PTAB and TTAB analytics are always at your fingertips.

API

Docket Alarm offers a powerful API (application programming interface) to developers that want to integrate case filings into their apps.

LAW FIRMS
Build custom dashboards for your attorneys and clients with live data direct from the court.

Automate many repetitive legal tasks like conflict checks, document management, and marketing.

FINANCIAL INSTITUTIONS
Litigation and bankruptcy checks for companies and debtors.

E-DISCOVERY AND LEGAL VENDORS
Sync your system to PACER to automate legal marketing.