A Dual Half-bridge Resonant DC-DC Converter for Bi-directional Power Conversion

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Abstract- This paper suggests A Dual Half Bridge DC-DC Converter for Bi-directional Power conversion. The LCL resonant converter operates as an isolated voltage amplifier with a constant voltage gain. The proposed topology minimize the number of switches and their associated gate driver components by using high frequency transformer which combine a half-bridge circuit together on the primary and secondary side. The voltage doublers circuit is employed on the secondary side. The current-fed input can limit the input current ripple. The parasitic capacitance of the switches is used for zero voltage switching (ZVS). Phase-shift and duty cycle modulation method is utilized to control the bidirectional power flow flexibly and it also makes the converter operate under a quasi-optimal condition over a wide input voltage range. With phase-shift control strategy, all the switches are operated under ZVS condition. The proposed converter achieves high efficiency because of the recycling of the leakage energies, reduction of the switch voltage stress, and interleaving of the converter. Finally a 400-W prototype is built for validation, where the experimental results indicate that the highest efficiencies in boost and buck modes are 99.9% and 99.8%, respectively.

Index Terms- LCL Resonant converter, Bi-directional DC-DC converter, Phase-shift, high voltage gain, isolated, interleaving, zero-voltage switching.

I. Introduction

In recent years, there has been a growing interest in generating electricity from distributed renewable energy sources. In many applications, it is required to connect multiple renewable energy sources of different types (eg wind and solar) and capacities to a power grid or load. To perform efficient power management and grid integration for the multiple sources, resonant DC-DC converters have been proposed.

The isolated dc-dc converter has multiple input ports for connecting different sources, such as photovoltaic (PV) panels, wind turbine generators (WTGs), fuel cells, and so on. The isolated DC-DC converter not only regulates the low-level dc voltages of the sources to a Constant high level required by the inverter, but also can provide other important control functions, for the renewable energy sources. To regulate the power flows of the converter phase-shift control is implemented.

Due to the high power density, bidirectional power flow, small in size, and weight, the BDC has received lots of attention. In distributed generation system, it requires energy storage device for grid connected operation mode and islanding mode. In that case BDC is used to charge and discharge the battery. The BDC can be formed by full-bridge or half-bridge converter and it can operate in high-power application. Several BDC topologies and control strategies based on half-bridge and full-bridge circuit have been proposed to achieve soft-switching or decrease current stress to switches.

The conventional topologies can achieve both step-up and step-down functions by means of replacing diodes with active switches, which are cost-effective, simple, and widely used. However, they have to operate at extreme duty ratio for higher voltage conversion. Due to the influences of the component's non-ideality like high switching and heavy conduction losses, actually their voltages gains will be far from that of an ideal one.

An interleaved IBDC is implemented, which possesses the merits of high conversion ratio, high efficiency, simple controller, and galvanic isolation. The IBDC is suitable for high power applications and energy storage systems. The primary side of the proposed converter has two power legs, which are in interleaved operation. In addition, a dual- LCD snubber is introduced at the primary for leakage energy recycling. In the secondary, quasi-series connection is designed to deal with high voltage. Based on the presented configuration, interleaved current at low voltage side can be obtained no matter in boost mode or buck mode.

The proposed topologies, a current–fed non-isolated is soft-switching bidirectional dc/dc converter is proposed. The proposed converter employs a current-fed half-bridge boost converter at front-end followed by an LCL resonant circuit to aid in soft-switching of semiconductor devices. A voltage doubler at output is selected to enhance the gain by 2X. The LCL resonant circuit also adds a suitable voltage gain. Therefore, the topology offers overall high voltage gain without transformer or large numbers of multiplier circuits.

Distributed Generation

Distributed generation, also called on-site generation, dispersed generation, embedded generation, decentralized generation, decentralized energy or distributed energy, generates electricity from many small energy sources

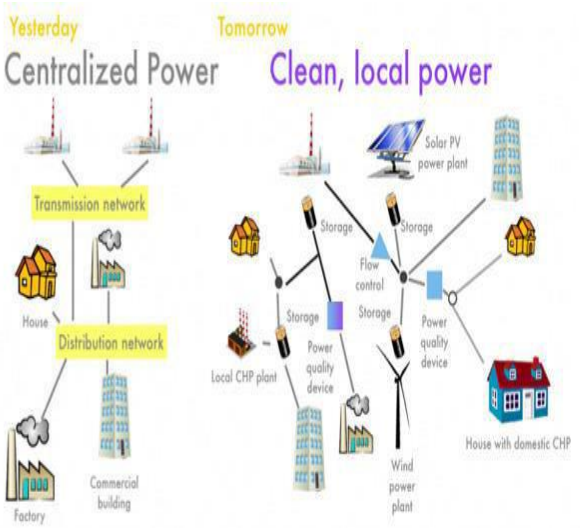

Figure1. Distributed Generation

Grid Connected PV System

Large scale PV plants are used for electricity generation that is fed into the grid. Such systems typically consist of one or more photovoltaic (PV) panels, a DC/AC power converter/inverter, racks, mounting fixtures, and electrical interconnections. Additionally, such systems could also include maximum power point trackers (MPPT), battery systems and chargers, solar trackers, software for energy management, solar concentrators etc. The electricity generated is either stored, used directly for self-consumption, or is fed into large electricity grids

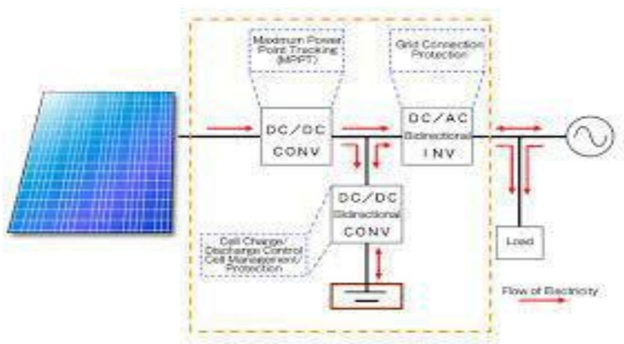

Figure2. Grid connected PV system

Wind Generation System

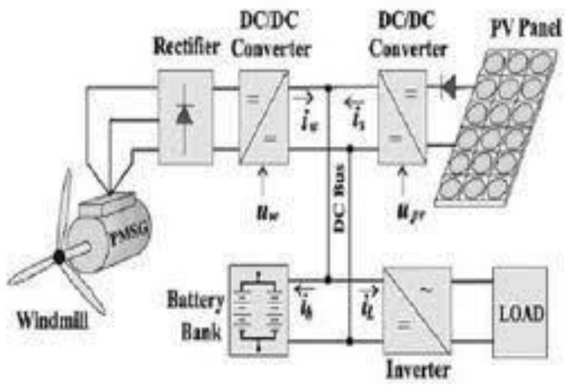

Figure3. Wind generation system

A novel power conditioning unit (PCU) for variable-speed micro wind turbine applications. It contains a simple generator-side rectifier, galvanic isolation with a simple dc–dc converter, and a single-phase full-bridge inverter at the grid side. Variable speed micro wind turbines based on a permanent magnet Synchronous generator (PMSG) are increasingly used in residential and small commercial buildings, despite their relatively low output voltage. Therefore, they can be used easily for battery charging, while their grid integration requires a PCU with galvanic isolation. Most of available PCUs provide no galvanic isolation, or use relatively complicated topologies or four stage energy conversion for that purpose. The dc–dc converter proposed allows reducing the complexity of the PCU.

II. Operation Principle of Proposed Converter

The Circuit configuration and control block diagram of the proposed converter, it consists of a half-bridge diode rectifier, an isolated resonant DC-DC converter. The proposed topology employs the resonant bi-directional dc converter to reduce the number of the power switches. The voltage doubler circuit in the secondary side is to get high voltage gain and avoid the flux walking. The bi-directional power flow can be controlled by the phase-shift angle. The use of voltage doubler circuits minimizes the number of switching devices and their associated gate components, the converter has the potential ability to achieve higher power density because of the smaller number of power components.

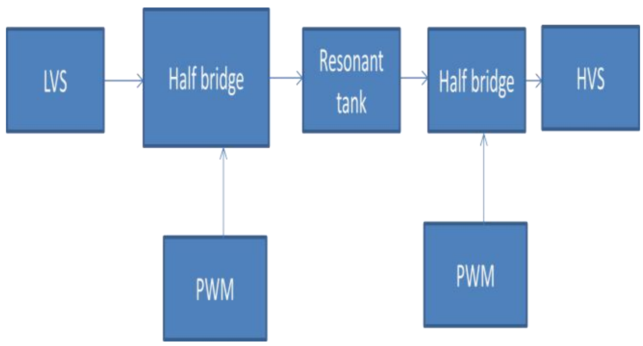

Figure4. Block diagram

The resonant DC-DC bidirectional converter, which can operate either in step-up or step-down mode by proper controlling. Due to the symmetrical structure in power stage and the control in interleaved pattern. To describe the operation of the converter, some assumptions are made as follows:

1. All the switches are ideal with anti-parallel body diodes and parasitic capacitors.
2. The capacitances $C_L C_5 C_6 C_7 \& C_8$ are large enough and to ignore the ripple and output voltage is controlled well and can be seen as constant.

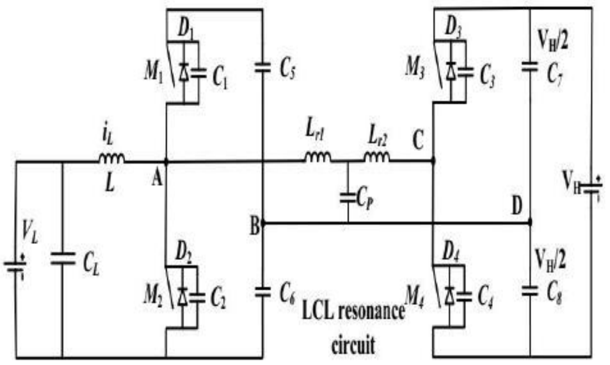

Figure5. Schematic of the proposed isolated bidirectional resonant DC converter

A. Step-up mode

1. In step up mode the energy transfers from, primary to secondary

2. The voltage is stepped through the transformer by switching the switches S1 and S2

3. In step-up mode, S1 and S2 are the main switches,

4. S3 and S4 are in charge of rectifying.

5. In this mode, switches S1 and S2 are controlled in interleaved manner and their duty ratio is maintained for output voltage level.

B. step-down mode

1. In step down mode the voltage flows from secondary to primary

2. The voltage is stepped down

3. As for step-down mode, S3 and S4 become main switches,

4. While the rest of switches, S1 and S2, server as rectifiers.

5. In step-down mode, the duty ratio of S3 (S4), D step-down, furnishes the voltage gain M step-down.

Simulation

This simulation is simulated by **PLECS** (Piecewise Linear Electronics Circuit Simulation) is a software tool for system-level simulations of electrical circuits developed by **PLEXIM.** It is especially designed for power electronics but can be used for any electrical network.

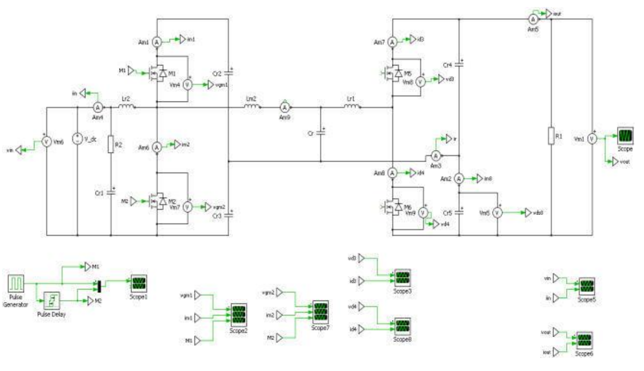

Figure6. Proposed simulation diagram for boost converter

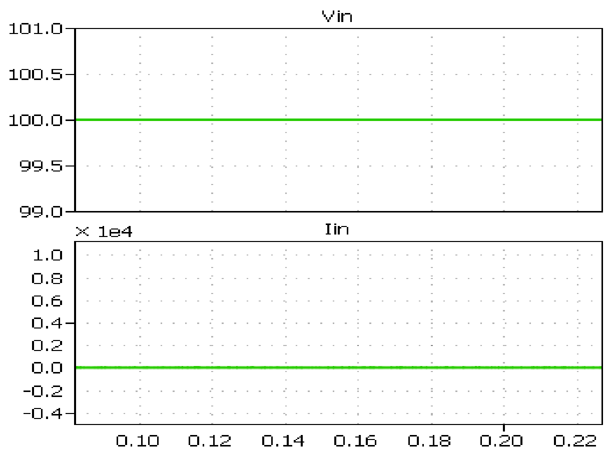

Figure7. Waveform for input voltage & current

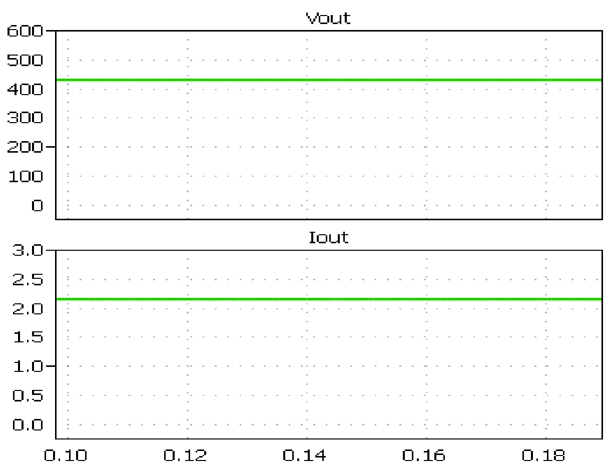

Figure8. Waveform for output voltage & current

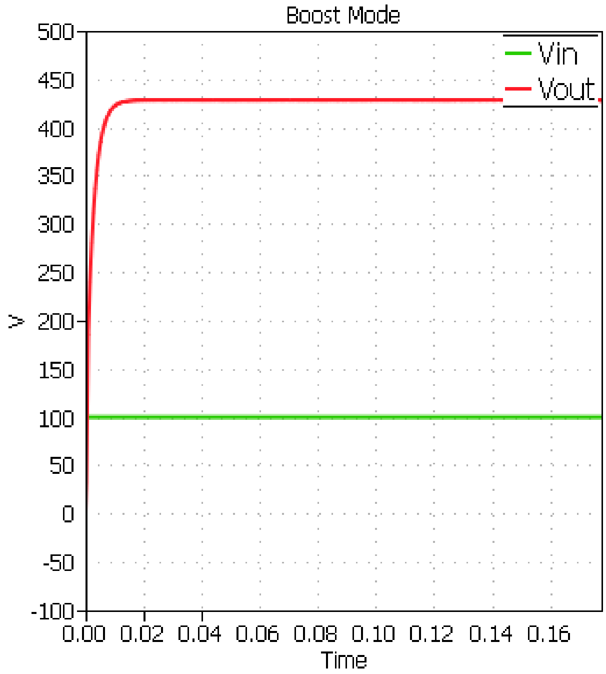

Figure9. Waveform for input & output voltage

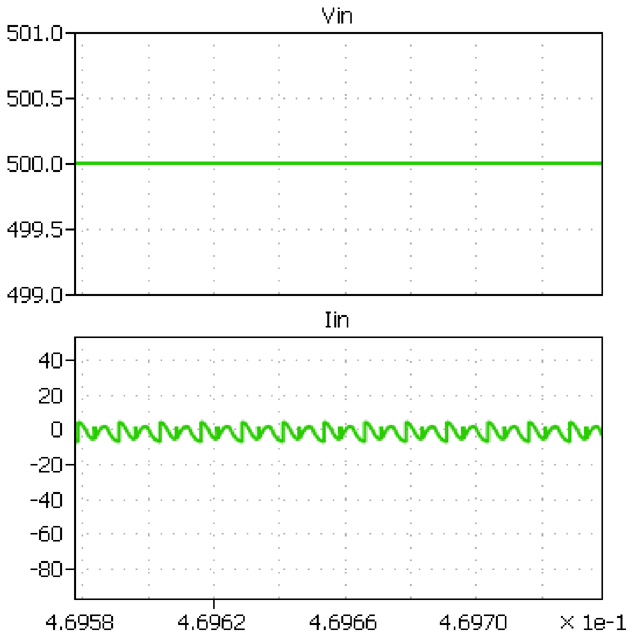

Figure12. Waveform for input voltage & current

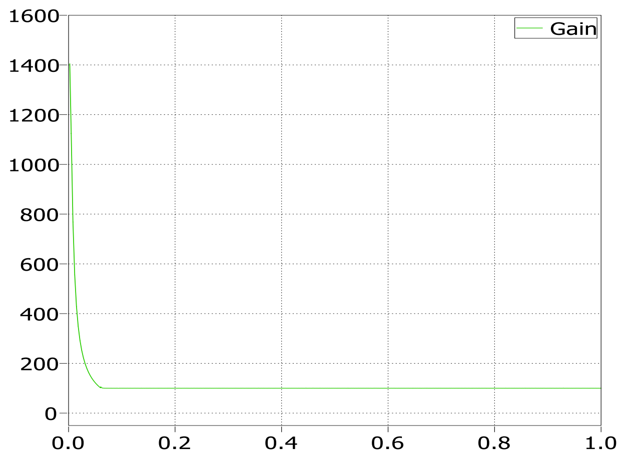

Figure10. Waveform for boost efficiency

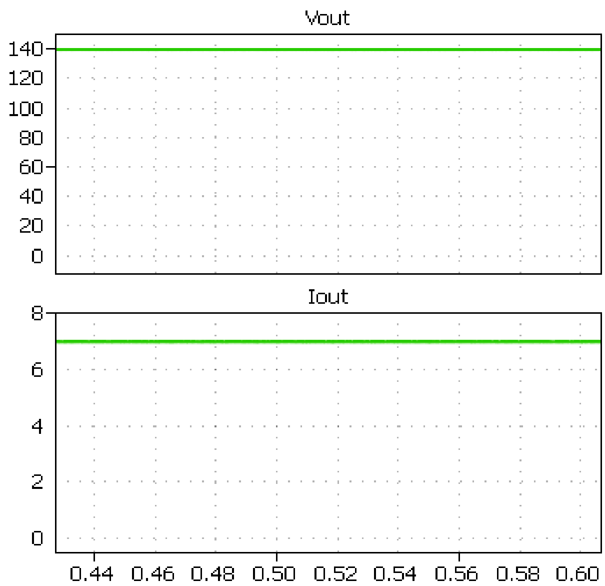

Figure13. Waveform for output voltage & current

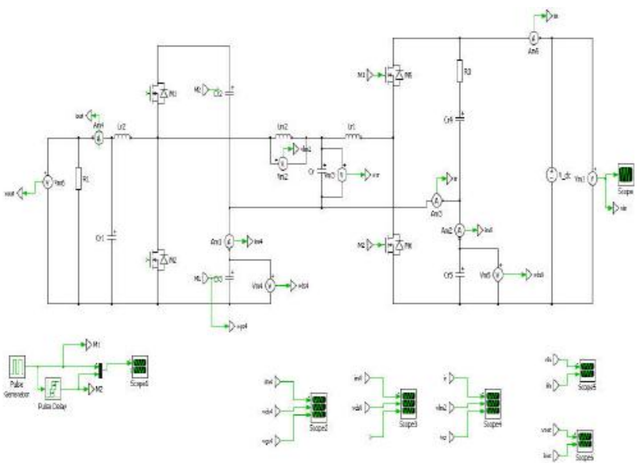

Figure11. Proposed simulation diagram for buck converter

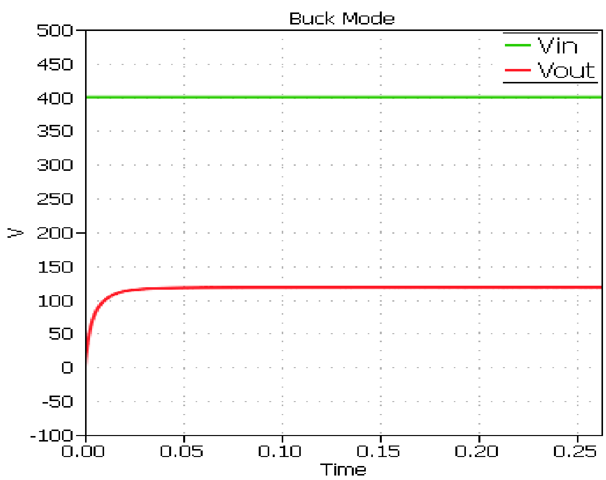

Figure14. Waveform for input & output voltage

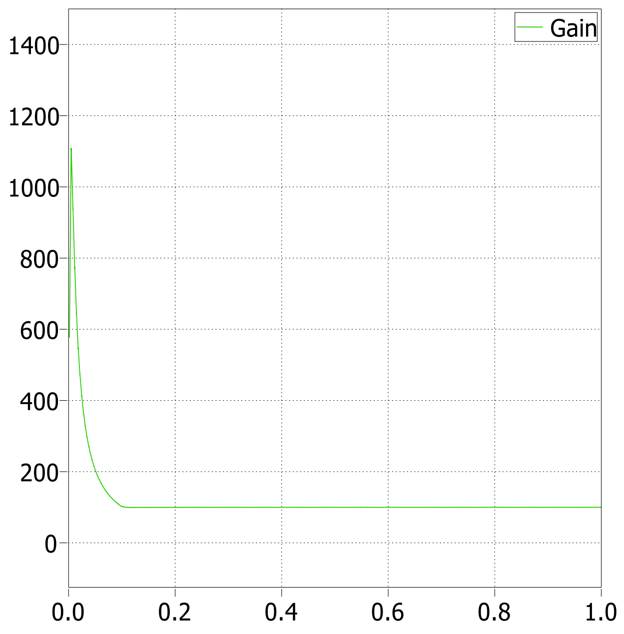

Figure15. Waveform for buck efficiency

Conclusion

The operation, design and control of isolated resonant bi-directional DC-DC converter are complex and comprehensive from semiconductor selection to peripheral circuit design and from long-timescale steady-state operation to short-timescale pulsed power phenomena. This paper analyzed the operation principles and various switching modes of the dual half bridge DC-DC converter, and derived the expression of current ripple. The relationship between voltage, current and power are derived and supported by the experimental of the prototype.

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