A Literature Survey on Bidirectional DC to DC Converter

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Abstract: **This paper presents the study of bidirectional DC to DC converter and comparing with the various existing method techniques. The proposed converter is designed in the manner of closed loop control. By using a controller, we can obtain a high output voltage and high gain by controlling the duty cycle of switches. The DC/DC converter is constructed by a buck-boost circuit, which is operated as a buck circuit when charging and a boost circuit when discharging. So we can use many power related systems, which improves efficiency, lower losses and higher performance**

Keywords: Bi-directional dc-dc converter, DC motor, Battery, Photovoltaic system, Controller.

I. INTRODUCTION

Basic dc-dc converters such as buck and boost converters (and their derivatives) do not have bidirectional power flow capability. This limitation is due to the presence of diodes in their structure which prevents reverse current flow. In general, a unidirectional dc-dc converter can be turned into a bidirectional converter by replacing the diodes with a controllable switch in its structure.

The bidirectional dc-dc converter along with energy storage has become a promising option for many power related systems, including hybrid vehicle, fuel cell vehicle, renewable energy system and so forth. It not only reduces the cost and improves efficiency, but also improves the performance of the system.

In the electric vehicle applications, an auxiliary energy storage battery absorbs the regenerated energy fed back by the electric machine. In addition, bidirectional dc-dc converter is also required to draw power from the auxiliary battery to boost the high-voltage bus during vehicle starting, accelerate and hill climbing. With its ability to reverse the direction of the current flow, and thereby power, the bidirectional dc-dc converters are being increasingly used to achieve power transfer between two dc power sources in either direction.

In renewable energy applications, the multiple-input bidirectional dc-dc converter can be used to combine different types of energy sources. This bidirectional dc-dc converter features galvanic isolation between the load and the fuel cell, bidirectional power flow, capability to match different voltage levels, fast response to the transient load demand, etc.

Recently, clean energy resources such as photovoltaic arrays and wind turbines have been exploited for developing renewable electric power generation systems. The bidirectional dc-dc converter is often used to transfer the solar energy to the capacitive energy source during the sunny time, while to deliver energy to the load when the dc bus voltage is low

Most of the existing bidirectional dc-dc converters fall into the generic circuit structure illustrated in Figure 1. 1, which is characterized by a current fed or voltage fed on one side. Based on the placement of the auxiliary energy storage, the bidirectional dc-dc converter can be categorized into buck and boost type. The buck type is to have energy storage placed on the high voltage side, and the boost type is to have it placed on the low voltage side.

To realize the double sided power flow in bidirectional dc-dc converters, the switch cell should carry the current on both directions. It is usually implemented with a unidirectional semiconductor power switch such as power MOSFET (Metal-Oxide-Semiconductor-Field-Effect-Transistor) or IGBT (Insulated Gate Bipolar Transistor) in parallel with a diode; because the double sided current flow power switch is not available. For the buck and boost dc-dc type converters, the bidirectional power flow is realized by replacing the switch and diode with the double sided current switch cell shown in Figure 1.2

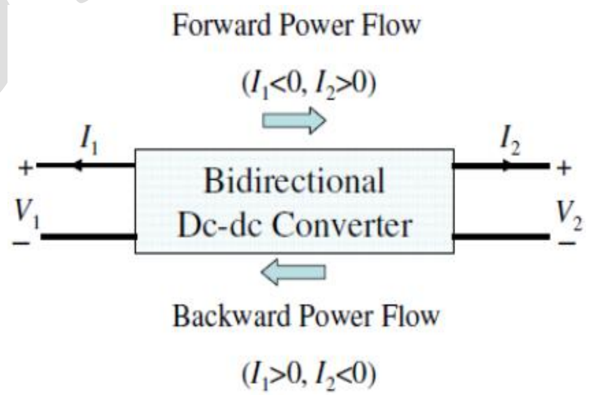

Figure 1 Illustration of bidirectional power flow

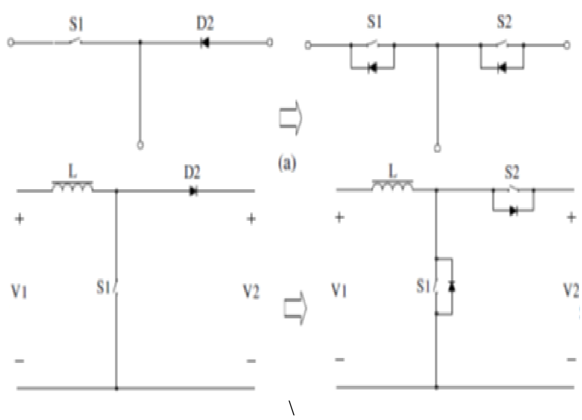

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Figure.2 Switch cell in bidirectional dc-dc converter

Basically they are divided into two types, non-isolated and isolated converters, meeting different application requirements

A. Non-isolated Bidirectional DC-DC Converters

In the transformer-less non-isolated power conversion systems, the boost type and buck type dc-dc converter are chosen usually. The high frequency transformer based system is an attractive one to obtain isolation between the source and load sides. But from the viewpoint of improving the efficiency, size, weight and cost, the transformer-less type is much more attractive. Thus, in the high power or spacecraft power system applications, where weight or size is the main concern, the transformer-less type is more attractive in high power applications.

Non-isolated BDCs (NBDC) are simpler than isolated BDCs (IBDC) and can achieve better efficiency the transformer-less type is more attractive in high power applications. For the present high power density bidirectional dc-dc converter, to increase its power density, multiphase current interleaving technology with minimized inductance has been found in high power applications.

The operation of the NBDC of Fig. 1.1.1. is as follows. The inductor is the main energy transfer element in this converter. In each switching cycle it is charged through source side active switch for the duration of *Ton=DT*, where *T=1/fsw* is the switching period and *D* is the duty cycle. This energy is then discharged to load during *Toff=(1-D)T*. In the four-switch buck boost converter (Fig. 1.1.2.) the principle of operation is the same. In the left to right power transfer mode, Q1 and Q4 act as active switches, while in the right to left power transfer the opposite switches (Q2 and Q3) are controlled. Synchronous rectification technique can be employed in this configuration in order to add more features and improve efficiency.

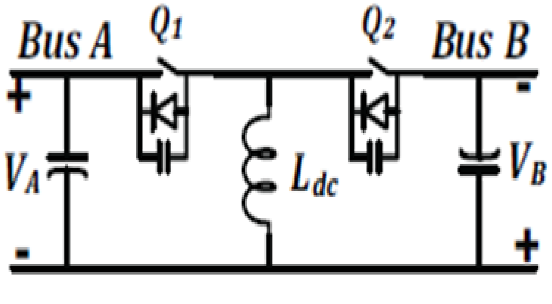

Figure 3 Bidirectional buck-boosts

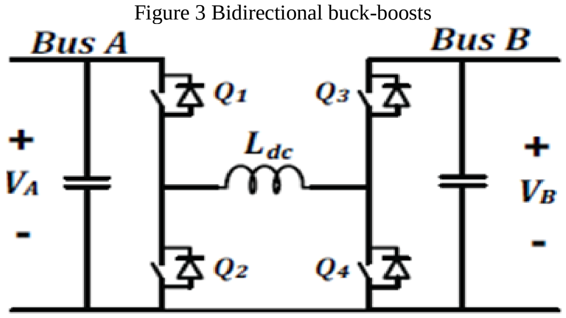

Figure 4 two back-to-back connected NBDC

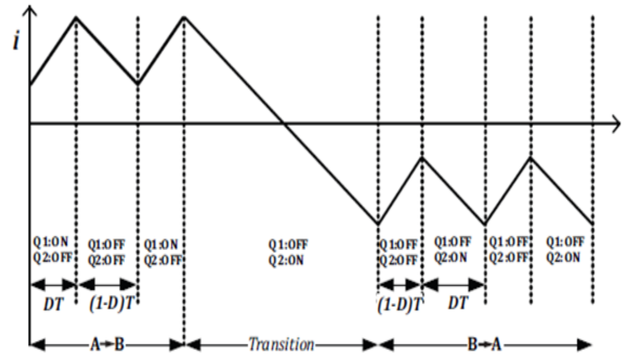

Figure5. Operating waveforms

B. Isolated Bidirectional DC-DC Converters

Galvanic isolation between multi-source systems is a requirement mandated by many standards. Personnel safety, noise reduction and correct operation of protection systems are the main reasons behind galvanic isolation.

Voltage matching is also needed in many applications as it helps in designing and optimizing the voltage rating of different stages in the system. Both galvanic isolation and voltage matching are usually performed by a magnetic transformer in power electronic systems, which call for an ac link for proper energy transfer.

In the bidirectional dc-dc converters, isolation is normally provided by a transformer. The added transformer implies additional cost and losses. However, since transformer can isolate the two voltage sources and provide the impedance matching between them, it is an alternative in those kinds of applications. As a current source, inductance is normally needed in between. For the isolated bidirectional dc-dc converters, sub-topology can be a full-bridge, a half-bridge, a push-pull circuit, or their variations. One kind of isolated bidirectional dc-dc converter is based on the half-bridge in the primary side and on the current fed push-pull in the secondary of a high frequency isolation transformer The converter operation is described for both modes; in the presence of dc bus the battery is being charged, and in the absence of the dc bus the battery supplies power. This converter is well suited for battery charging and discharging circuits in dc uninterruptible power supply (UPS). Advantages of this proposed converter topology include galvanic isolation between the two dc sources using a single transformer, low parts count with the use of same power components for power flow in either direction.

The dual active bridge dc-dc converter with a voltage-fed bridge on each side of the isolation transformer operates utilization of the leakage inductance of the transformer as the main energy storing and transferring element to deliver bidirectional flow power.

C. IBDC structure

Most, if not all, of medium-power IBDCs have a structure similar to Fig. 1.2.1 this structure consists of two high-frequency switching dc-ac converters and a high-frequency transformer which is primarily used to maintain galvanic isolation between two sources. This transformer is also essential for voltage matching in case of large voltage ratio between two sources. The transformer calls for ac quantities at its terminals and thus a dc-ac converter is employed on each side. As energy transfer in either direction is required for the system, each dc-ac converter must also have bidirectional energy transfer capability. With the same token, the dc buses in this structure must also be able to either generate or absorb energy.

The dc buses shown in this structure are assumed to have stiff-voltage characteristics, i.e. their Thevenin impedance is negligible. In practice, these buses are connected to a dc source or an active load like battery, ultra-capacitor or dc-link capacitor which resemble an ideal voltage source with stiff voltage characteristics. If the converter is of current-fed type, it is assumed that the required elements to realize stiff current are incorporated inside the converters shown in Fig 1.2.1

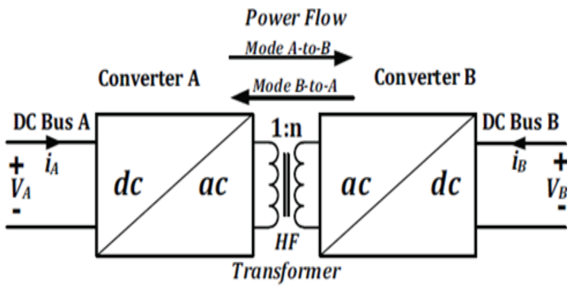

Figure 6 Basic structure of an IBDC

Considering Fig. 1.2.1, an important characteristic of an IBDC is the type of converter at each side. Basically, two types of switching converters can be identified. A current-type (or current-fed) structure has an inductor with stiff current characteristic at its terminals which acts like a current source, like conventional boost converter at its input terminals. A voltage type (or voltage-fed) structure has a capacitor with stiff voltage characteristic at its terminals which acts like a voltage source, like conventional buck converter at its input terminals

D. Applications

Nowadays about 62% of crude oil used in United States is refined into gasoline for transportation. The associated energy security and green house gas emission problems are well known. Hybrid electric vehicles (HEV's) is one of the solutions to address these issues, because the fuel economy has been improved by optimizing internal combustion engine (ICE) efficiency, regenerating brake energy and shutting down ICE during the idle time. After more than one million HEV's are driven on the road today, there is a growing interest on plug-in hybrid electric vehicles (PHEV's), which is defined by IEEE-USA's Energy Policy Committee as (1) a battery storage system of 4kWh or more, used to power the motion of the vehicle, (2) a means of recharging that battery system from an external source of electricity, and (3) an ability to drive at least 10 miles in all-electric mode consuming no gasoline .PHEV's can be power by electricity from various sources, including emerging renewable power generations, and benefit from lower fuel (electricity) cost.

II. LITERATURE SURVEY

Hua Bai et al**.,** conducted a study on bidirectional DC-DC converter in a HEV. This DC-DC converter is a high-power converter that links the high voltage battery (HV) at a lower voltage with the high voltage DC bus. The typical voltage of a battery pack is designed at 300 to 400V. The best operating voltage for a motor and inverter is around 600V. Therefore, this converter can be used to match the voltages of the battery system and the motor system. Other functions of this DC-DC converter include optimizing the operation of the power train system, reducing ripple current in the battery, and maintaining DC link voltage, hence, high power operation of the power train.

R.Goutham Govind Raju et al., formulated a zero voltage switching (ZVS) bidirectional isolated DC-DC converter. This is used in high power application especially for power supply in fuel cell vehicles electric vehicle driving system and power generation where a high power density is required. This technique has the advantages of low cost, light weight and high reliability power converter where the power semiconductor devices (MOSFET, IGBT, etc) and packaging of the individual units and the system integration play a major role in isolated DC/DC converter hybrid/fuel cell vehicles.

Young-Joo Lee et al.,, formulated a novel integrated bidirectional ac/dc charger and dc/dc converter (henceforth, the integrated converter) for PHEVs and hybrid/plug-in-hybrid conversions is proposed. The integrated converter is able to function as an ac/dc battery charger and to transfer electrical energy between the battery pack and the high-voltage bus of the electric traction system

Lisheng Shi et al., presented the basic requirements and specifications for PHEV bidirectional ac dc converter designs. Generally, there are two types of topologies used for PHEVs: an independent topology and a combination topology that utilizes the drive motor's inverter. Evaluations of the two converter topologies are analysed in detail. The combination topology analysis is emphasized because it has more advantages in PHEVs, in respect to savings in cost, volume and weight.

Tanmoy Bhattacharya et al., proposed a multi-power-port topology which is capable of handling multiple power sources and still maintains simplicity and features like obtaining high gain, wide load variations, lower output-current ripple, and capability of parallel-battery energy due to the modular structure. The scheme incorporates a transformer winding technique which drastically reduces the leakage inductance of the coupled inductor.

João Silvestre et al., designed a bidirectional DC-DC converter for a small electric vehicle. The DC-DC converter designed and tested is capable of raising the voltage from the battery pack (96V nominal) to 600V necessary to feed the Variable Frequency Drive that controls the induction motor,. This converter is also capable of working in the opposite direction (600V to

96V) in order to capture energy from regenerative braking and downhill driving.

Hyun-Wook Seong et al., describes non-isolated high step-up DC-DC converters using zero voltage switching (ZVS) boost integration technique (BIT) and their light-load frequency modulation (LLFM) control. The proposed ZVS BIT integrates a bidirectional boost converter with a series output module as a parallel-input and series-output (PISO) configuration.

Zhe Zhang et al., designed a bidirectional isolated DC-DC converter controlled by phase-shift and duty cycle for the fuel cell hybrid energy system is analysed and designed. The proposed topology minimizes the number of switches and their associated gate driver components by using two high frequency transformers which combine a half-bridge circuit and a full-bridge circuit together on the primary side.

Problem formulation

Most of the existing bidirectional dc-dc converters fall into the generic circuit structure, which is characterized by a current fed or voltage fed on one side.

The Bi-directional dc-dc converter fed DC motor drive. In this topology, boost converter operation is achieved by modulating Q2 with the anti-parallel diode D1 serving as the boost-mode diode. With the direction of power flow reversed, the topology functions as a buck converter through the modulation of Q1, with the anti-parallel diode D2 serving as the buck-mode diode. It should be noted that the two modes have opposite inductor current directions. A new control model is developed using modern controller to achieve both motoring and regenerative braking of the motor. A Lithium-ion battery model has been used in this model to verify the motor performance in both motoring and regenerative mode. This controller shows satisfactory result in different driving speed commands.

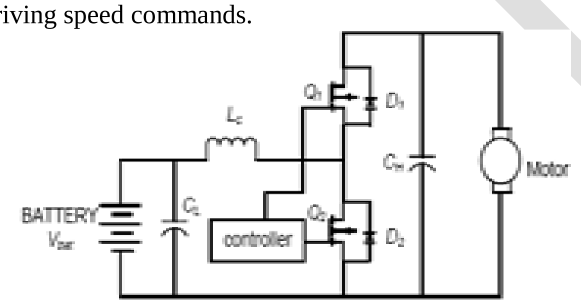

Figure 7 Bidirectional dc-dc converters with battery and dc motor

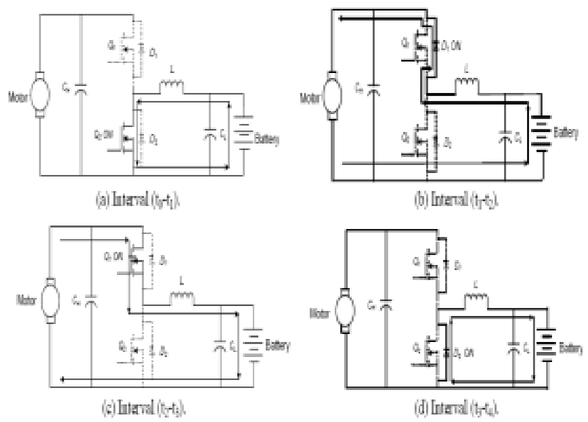

Figure 8 Converter operating modes.

III. CIRCUIT DESCRIPTION

Converter operation: The bidirectional dc-dc converter shown in Figure1 is operated in continuous conduction mode for forward motoring and regenerative braking of the dc motor. The MOSFETs *Q1* and *Q2* are switched in such a way that the converter operates in steady state with four sub intervals namely interval *1(t0-t1),* interval *2(t1-t2),* interval *3(t2-t3)* and interval *4(t3-t4).* It should be noted that the low voltage battery side voltage is taken as *V1* and high voltage load side is taken as *V2.* The gate drives of switches *Q1* and *Q2* are shown in Figure 3. The circuit operations in steady state for different intervals are elaborated below.

Interval 1(t0-t1): At time *t0*, the lower switch *Q2* is turned ON and the upper switch *Q1* is turned OFF with diode *D1, D2* reverse biased as shown in Figure 2(a). During this time interval the converter operates in boost mode and the inductor is charged and current through the inductor increases.

Interval 2(t1-t2): During this interval both switches *Q1* and *Q2* is turned OFF. The body diode *D1* of upper switch *Q1* starts conducting as shown in Figure 2(b). The converter output voltage is applied across the motor. As this converter operates in boost mode is capable of increasing the battery voltage to run the motor in forward direction.

Interval 3(t2-t3): At time *t3*, the upper switch *Q1* is turned ON and the lower switch *Q2* is turned OFF with diode *D1, D2* reverse biased as shown in Figure 2(c). During this time interval the converter operates in buck mode.

Interval 4(t3-t4): During this interval both switches *Q1* and *Q2* is turned OFF. The body diode *D2* of lower switch *Q2* starts conducting as shown in Figure 2(d).

Converter design: The bi-directional converter is designed based on the input supply voltage and output voltage requirement to drive the electric vehicle at desired speed. The converter power topology is based on a half bridge circuit to control the dc motor.

IV. OBJECTIVE

In Proposed systems, the bidirectional dc-dc converter along with energy storage has become a promising option for many power related systems, including hybrid vehicle, fuel cell vehicle, renewable energy system, industries and so forth. The proposed converter is designed in the manner of closed loop control. Because closed loop control have advantages than open loop control. By using modern controller, we can obtain a high output voltage and high gain by controlling the duty cycle of switches. So it **reduces switching current, frequency, high output voltage**. We can **reduce the heat loss,** which can increase the switches life span. Not only **reduces the cost** and

improves efficiency, but also improves the **performance** of the system.

- To improve the electric power storage from renewable energy systems.
- To design an electric vehicle by using PV array, Bidirectional converter, Battery bank, etc.
- To generate the electric power continuously in an electric vehicle with low cost of generation.
- To determine the best control for controlling duty cycle
- To drive a long distance without using any external sources in electric vehicle.

To make a pollution free environment with minimum power loss by using this method.

V. METHODOLOGY

To design a Bidirectional converter for renewable energy systems, the complete prototype is carried in the following sequences, they are given in steps. Finalizing the total circuit diagram, listing out their components and their sources of procurement. Procuring the components, testing the components and securing the components. Making the model as per the circuit diagram on the breadboard and testing the results. Making layout, preparing the inter connection diagram as per the circuit diagram, preparing the drilling details, cutting the laminate to the required size. Drilling the holes on the board as per the component layout, painting the tracks on the board as per the inter connection diagram.. Etching the board to remove the unwanted copper older than track portion. Then cleaning the board with water and solder coating the copper tracks to protect the tracks from rusting or oxidation due to moisture. Integrating the total unit, inter wiring the unit and finally testing the unit. Keeping the unit ready for demonstration.

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