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Isolated Bidirectional Half Bridge Dc-Dc Converter With A Flyback Snubber And Two Passive Capacitor-Diode Snubber

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Abstract: The Bidirectional Dc–Dc Converters have been widely studied for various Industrial Applications such as Auxiliary Power Supplies, Renewable Energy System, Hybrid Electric Vehicles, Fuel Cell-based Dc–Dc Converters, Battery Charged/Discharged Converter and Uninterruptible Power Supplies System. In the Electric Vehicle System, the Energy storage devices and its Charging/Discharging control techniques are necessary. However, these Topologies with Isolated Transformers have High-conduction losses, because the usual number of power switches is between Four and Nine. In order to solve these problems, the Bidirectional Dc Converter is proposed in this paper for Charging and Discharging Batteries that are utilized in Energy systems A Bidirectional Half bridge Dc-Dc Converter provides with an Active Flyback and Passive Capacitor Diode Snubber. It consists of Low and high side switches which can operate near Zero Voltage Switching and Zero Current Switching. Passive and Active Snubbers in the circuit were suggested to reduce the voltage spikes. This Snubber arrangement not only reduce the Voltage spikes but also relieves the drawbacks of high current and high voltage stress inflict on the main switches at both Turn On and Turn Off. It is typically arranged with Boost and Buck type Topologies and it is simulated by using MATLAB SOFTWARE.

Keywords: Bidirectional DC-DC Converters, Flyback snubber, Passive Capacitor Diode Snubber, Voltage Spikes, Zero Voltage Switching, Zero Current Switching.

1 INTRODUCTION

In renewable supply of Dc generally batteries are used for back up the power. Recent years, the development of high power Isolated Bidirectional DC-DC Converters has become a popular concept because of the requirements of fuel cell vehicle applications and battery based energy storage systems. Bidirectional Dc–Dc Converter is needed for Cold start and Battery Recharge. For cold start, the Dc–Dc Converter boosts the 12V battery voltage to a desired high voltage (normally 150–300 V) for the fuel cell to start. Power Converters typically configured of semiconductor devices such as Transistors,Diodes, Energy Storage Elements such as Inductors,Capacitors, and Controller to regulate the output voltage. Transistor type devices like BJTs (Bipolar Junctions Transistors), MOSFETs (Metal Oxide Silicon Field Effect Transistors) and IGBTs (Insulated Gate Bipolar Transistors) are used as switches in power electronic converters and are made to operate as switches that are either fully on or fully off at any given time.

While MOSFET is considered over here since MOSFETs are widely used in power electronic applications such as high frequency inverters used at the front ends of high efficiency AC Motor Drives, high and very high frequency Dc-Dc Converters,
Power factor Correction Modules etc.Once the fuel cell is started, the Dc-Dc Converter recharges the battery from the fuel cell or regenerative braking. In order to increase efficiency, soft-switching technology has been widely used in Dc-Dc Converters. However, most of the existing soft-switched Dc–Dc converters are low power or unidirectional and often are difficult to meet the necessities. Half-bridge bidirectional Dc–Dc converters with soft switching are considered as one of the foremost option for these applications. The use of a Bi-directional Dc-Dc Converter fed Dc Motor Drive devoted to Electric Vehicles (EVs) application allows a suitable control of both Motoring and Regenerative Braking operations, and it can contribute to a significant increase the Drive system overall efficiency. Recently many Bi-directional Dc-Dc Converter topologies have been described with Soft Switching Technique to increase the Transfer Efficiency. In past studies, bridge-type bidirectional isolated converters have been widely applied to Fuel cell and Electric Vehicle Driving systems. For raising Power level, a Dual Full Bridge configuration is usually adopted and their low and high sides are typically arranged with Boost and buck-type topologies respectively. However, component stress, switching loss, and Electromagnetic Interference (EMI) noise are increased due to Diode Reverse Recovery Current and MOSFET Drain Source Voltage, resulting in low reliability. Due to leakage inductance of the isolation transformer, it results in high voltage spike during switching transition. A possible solution for the leakage inductance to raise its current level up so that it can reduce their current difference and which in turn it reduces voltage spike too. As the current level varies

with certain load condition and it is hard to tune these two currents during switching timing. Therefore, a passive or an active Snubber circuit is required. Passive and active clamp circuits were configured to reduce the voltage spike by varying the current difference between the Current-fed Inductor and Inductance leakage currents.

On the other fact, a simple active clamping circuit is used. however, the current stress is increased due to resonant current. An Isolated Bidirectional Converter with a Flyback Snubber was consequently proposed .In Flyback Snubber, current does not circulate through the main switches and also recycle the absorbed energy which is stored in the clamping capacitor. By this current stress can be reduced a lot under heavy-load condition. Moreover, the Flyback Snubber avoid the inrush current during start up period. The low and high-side switches with Hard Switching Turn off results in high-voltage spikes. To solve this problem, we first initiate two Buffer Capacitors ($Cb1$ and $Cb2$) connected in parallel with the upper legs of the voltage fed bridge.With these two buffer capacitors, the low- and high-side switches can operate with Zero Voltage Switching (ZVS) and Zero Current Switching (ZCS).

2 LITERATURE SURVEY

In Existing papers, there is an increasing demand of Bidirectional DC-DC Converters in applications like Dc Uninterruptible Power Supplies and the leakage inductance in the coupled inductor suffer from switching loss and voltage stress on the switching devices and amplify the adverse effects created by the parasitic circuit elements, such as the leakage inductances of the coupled inductors.The fuel cell output voltage drops quickly when first connected with a load and gradually decreases as the output current rises.The fuel cell also lacks energy storage capability.

3 PROPOSED CONVERTER

DC is the Unidirectional flow of electric charge Direct current is produced by sources such as Batteries,Solar Cells and Commutator Type Electric Machines .It may be obtained from an Alternating Current Supply by use of a current-switching arrangement called a Rectifier,which contains electronic elements that allow current to flow only in one direction.It is also used to charge the batteries and in nearly all electronic systems as the power supply. A Diode Bridge is an arrangement of four (or more) Diodes in a Bridge circuit configuration that provides the same polarity of output for either polarity of input. When used in its most common application, for conversion of an Alternating Current (AC) input into a Direct Current (DC) output, it is known as a Bridge Rectifier. A bridge rectifier provides full wave rectification from a two-wire AC input, resulting in lower cost and weight as compared to a rectifier with a 3-wire input from a transformer with a Center Tapped Secondary Winding or a Three-phase AC input, a half wave rectifier consists of Three diodes, but a fullwave bridge rectifier consists of six diodes.. High Frequency Transformer transfer electric power. The physical size is dependent on the power to be transferred as well as the operating frequency. Frequencies are usually between 20 and 100k and it can be determined depending on the transfer power and Switching Frequency. The voltage $V1$ at the primary side of the transformers has a rectangle shape. This causes an input current $I1$, which is the addition of the back transformed secondary current $I2$ and the magnetising current IM . To keep the magnetising current IM low, a magnetic core without an air gap is used. The magnifying current is approximately proportional to the magnetic flux or flux density. The input voltage $V1$ determines the magnetic flux. The physical correlations are given by Faradays law of induction:

$V = N \times \mathrm{dF}$ - - - - (1)

A. Step down Transformer

When AC is applied to the primary winding of the power transformer it can either be stepped down or up depending on the value of DC needed. In this circuit the transformer of 230V/12-0-12V is used to perform the step down operation where a 230V AC appears as 12V AC across the secondary winding. One alteration of input causes the top of the transformer to be positive and the bottom negative. The next alteration will temporarily cause the reverse. The current rating of the transformer used in this project is 500mA. Apart from stepping down AC voltages, it gives isolation between the power source and power supply circuits.

B. Half-bridge converter

Two capacitors C1 and C2 have half of d.c. input voltage across of each. The voltage, 0.5 V1 is switched across the primary winding by MOSFET T1 and T2 alternately. The switch that is off will have the full d.c. voltage across it. The output voltage Vo is:-

Vo = V1 x D x (Ns/Np) - - - - (2)

C. Comparison of Full Bridge and Half Bridge

Each switching device in the full bridge is subject to a voltage stress equal to dc-input voltage (Vdc),and current stress is load current(Iac).TDR=4*Pa Pa=Output power For the half bridge each switching device's voltage stress is equal to twice the dc-input voltage (2Vdc), and current stress is load current (Iac). TDR=4*Pa. The total device rating is the same for the half bridge and full bridge for the same output power.. Full-bridge topology uses four switches where as Half-bridge topology uses two switches.

4 PROBLEM DEFINITION

A.Losses in Semiconductor Switches

The semiconductor switches used in power converters are the source of energy losses. The main losses that are related with these switches are conduction losses and switches losses, Switching Losses. In a real semiconductor switch, the switch voltage or switch current do not go to zero instantaneously at the instant of turn-on or turn-off. There is a duration of time during any switching transition (i.e. switch turn-on and turn-off) when there is both voltage across and current through the switch.

B. Power Loss & Switching Loss

The Power loss during each switching instant is the overlapped area of the switch current and voltage waveforms at the instant of turn-on or turn-off of the switch. Since the average power is energy divided by the period, higher switching frequencies lead to higher switching losses. Sharp and sudden switching Switching Losses. In a real semiconductor switch, the switch voltage or switch current do not go to zero instantaneously at the instant of turn-on or turn-off. There is a duration of time during any switching transition (i.e. switch turn-on and turn-off) when there is both voltage across and current through the switch. The corresponding power loss during each switching instant is the overlapped area of the switch current and voltage waveforms at the instant of Turn-on or Turn-off of the switch. Since the average power is energy divided by the period, higher switching frequencies lead to higher switching losses.

Sharp and sudden switching in a MOSFET, the main switching losses are caused by the charging and discharging of the output capacitance to and from the off state voltage that the MOSFET is subjected to, while the tailing of current is the primary cause of switching losses in IGBTs. Turning on and turning off the power electronic switches with such switching losses is known as “hard switching”. Soft Switching

The problems of switching losses and EMI associated with hard-switching converter operation can be reduced by using soft-switching. The term "soft-switching" in power electronics refers to various techniques where the switching transitions are made to be more gradual to force either the voltage or current to be zero while the switching transition is being made. EMI is reduced by soft-switching because the switching transitions from on to off and vice versa are gradual and not sudden. Switching losses are reduced since the power dissipated in a switch while a switching transition made is proportional to the overlap of the voltage across the switch and the current flowing through it. Soft-switching forces either the voltage or the current to be zero during the time of transition,therefore there is no overlap between voltage and current and (ideally) no switching loss. There are two types of soft-switching namely Zero Voltage Switching (ZVS) and Zero Current Switching (ZCS). Although there are many ZVS and ZCS techniques, there are general principles associated with each type.

5 METHODOLOGY

The proposed soft-switching bidirectional isolated half bridge converter with an Active Flyback and Two Passive Parallel Capacitor Diode Snubbers .It can be function with two types of conversions namely step-up conversion and stepdown conversion.It consists of active flyback Snubber at the low-voltage side(Vin ,Low) and a Passive Snubber pair at the high voltage side(Vin,High). Inductor acts as output filter when power flows from the high-voltage side to the low-voltage side, which is termed as a step-down conversion

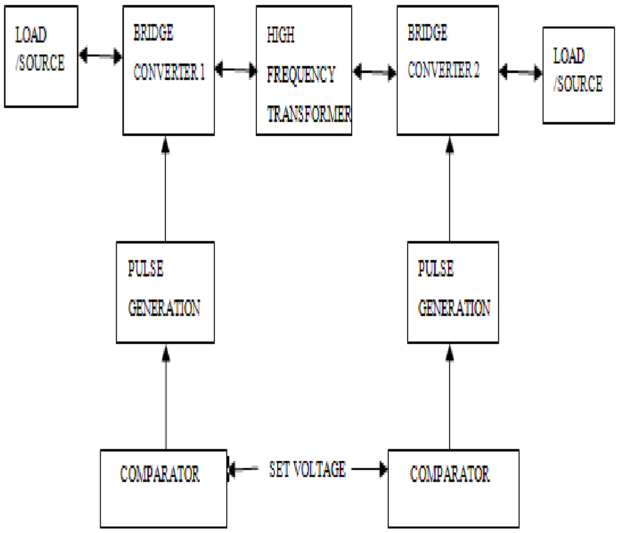

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Fig.1 Proposed Block Diagram

On the other side, it works in the step-up conversion. Moreover, Snubber Capacitor and Diode are used to absorb the current difference between current-fed inductor current and leakage inductance curren of isolation transformer during switching commutation.The Flyback Snubber transfer the energy which is in Snubber Capacitor to Passive Parallel Capacitors *Cb*1 and *Cb*2, when voltage across the capacitor drop to zero.

A Step-Up Conversion

In the step-up conversion, switches M1 & M4 acts like a boost converter, where (*M*1,*M*2) and (*M*3,*M*4) switches conduct to store energy in *Lm* which is charged by Vin,Low.A detailed mode of converter operation as follows:

Mode 1 : Before *the* start up period all of the four switches *M*1, *M*4 are turned on. Inductor *Lm* is charged by *Vin* ,low. At this time *M*1 and *M*4 remains in On state, while *M*2 and *M*3 will be in off state and flyback Snubber will be in Off mode. Since the Snubber Capacitor Cc is charged by Ic. Lm is charged by Vin, Low.

Mode 2: In this mode, primary current will track the inductance current and the parallel capacitor will start to release energy.

Mode 3 : The Energy stored in Passive Parallel Capacitor *Cb*1 is not fully discharged yet. Thus, the Capacitor will not stop discharging until Voltage across *Cb1* drops to zero. When the Energy stored in Parallel Capacitor *Cb*1 has been completely released to the load, Diode *D*5 will conduct at this mode.

Mode 4: All of the four switches M1 ,M2,M3 M4 are turned on again, and switch *MS* of the flyback snubber is turned on instantaneously. Switches *M*2 and*M*3 achieve a ZCS turn-on i.e junction capacitor energy is completely lostand primary current drops to zero gradually. In the flyback Snubber, the energy stored in Clamping Capacitor will be delivered to the magnetizing inductance of the Flyback Snubber Transformer

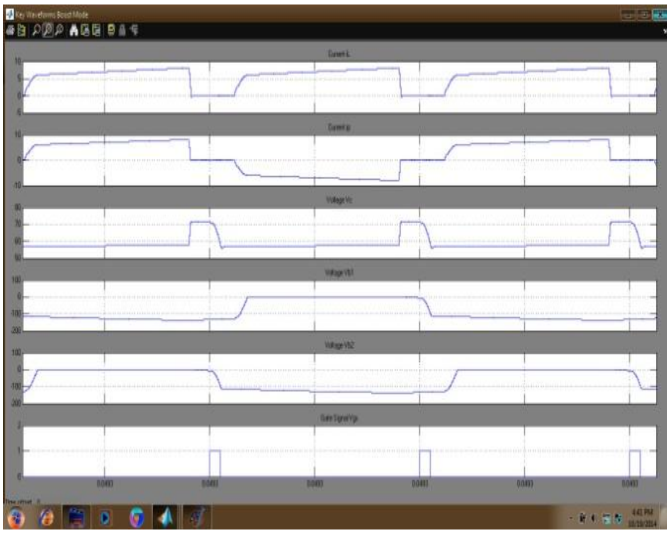

Fig.2 Key waveform for boost converter

Mode 5: When Flyback Snubber switch Ms is turned off,capacitor voltage drops to zero, and the energy stored in the magnetizing inductance in the flyback Snubber will be transferred to passive parallel capacitor *Cb*1 and the circuit operation is Similar to a regular turn-on state.

The waveform for MOSFET DRAIN SOURCE Voltage as follows

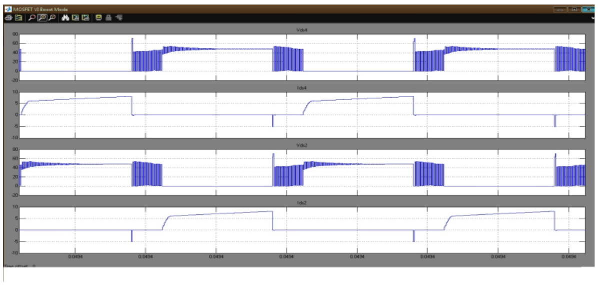

Fig.3 Voltage (Vds2 & Vds4) and Current(Ids2 & Ids4) waveform of MOSEFET during Boost converter mode of operation

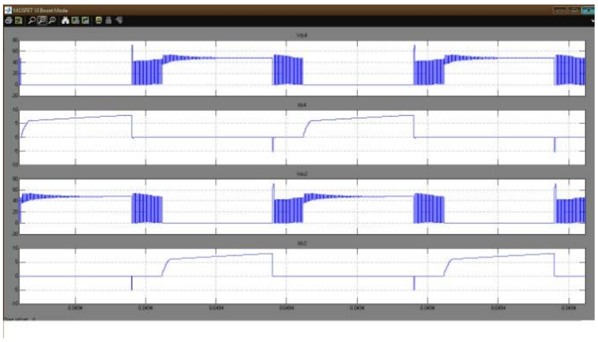

Fig.4 Transformer Primary and Secondary Voltage ,Primary and Secondary Current waveform during Boost mode of operation

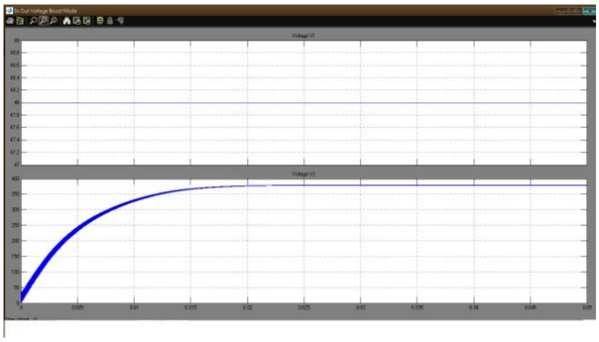

Fig.5 Measured input (Vin =48v) and output(380v) Voltage of Boost Converter.

B. Step-Down Conversion

In the step-down conversion, switches *M*5 ,*M*8 are operated as Buck converter in which switch pairs (*M*5,*M*8) and (*M*6,*M*7) take turns conducting to transfer power from Capacitor to Battery.

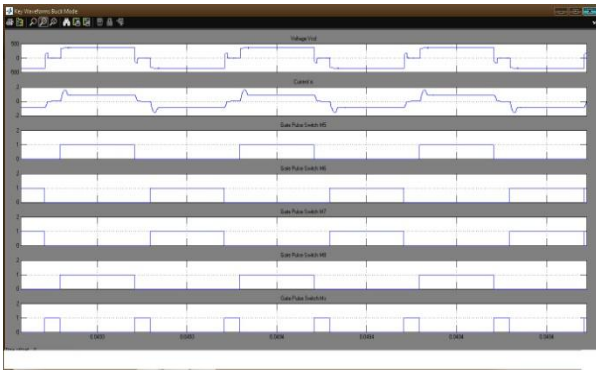

Fig.6 Key waveform for buck converter

Mode 1: In this mode, switches*M*5 and*M*8 conducts. The high-side voltage *V*in,high is crossing the transformer, equivalent inductance and the diodes (*D*1 and *D*4) conducts to transfer power, and the voltage across the transformer terminals on the Vin, low changes immediately to reflect the voltage from the Vin ,high

Mode 2 :In this mode switch*M*8 remains conducting,. The diode of *M*6 conducts and transfers the energy from Clamping Capacitor to Cb1& Cb2 .After this switch *M*6 Conducts by attaining ZVS Switching while *M*8 is turned off.

Mode 3: When Energy *Cb*2 is fully discharged, at ZCS turn off condition therefore diode *M7* conducts with ZVS.The circuit operation completes a half-switching cycle.

The waveform for MOSFET DRAIN SOURCE Voltage as follows

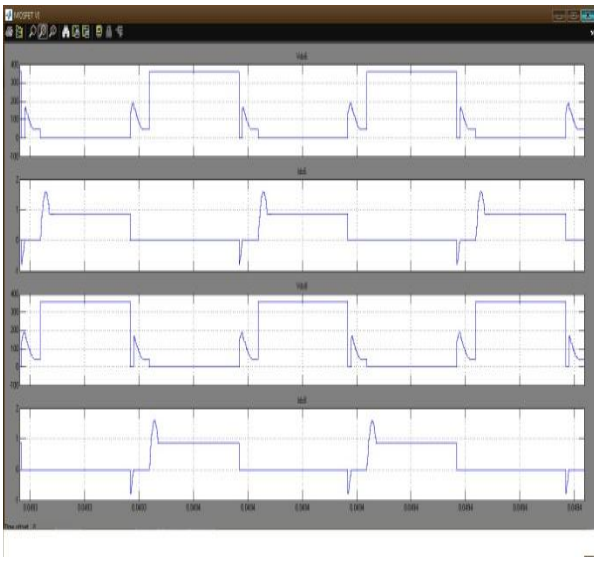

Fig.7 Voltage(Vds6 & Vds8) and Current(Ids6 & Ids8) waveform of MOSEFET during Buck converter mode of operation.

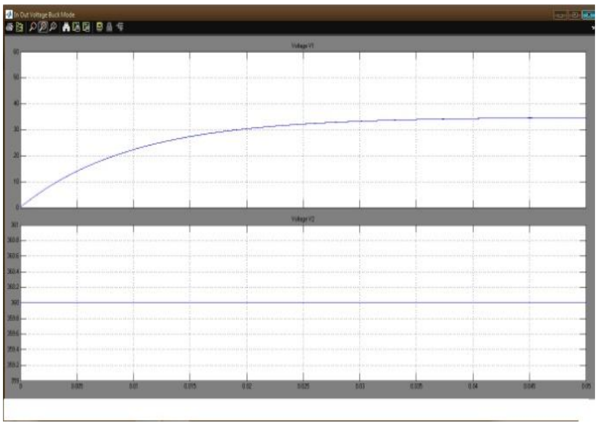

Fig.8 Measured input (Vin=360v) and output(32v)voltage of Buck Converter.

6 CONCLUSION

This Isolated Soft-Switching Bidirectional Half bridge DC-DC converter reduces the voltage and current spikes and also reduces the drawbacks of voltage and current stress during TURN ON and TURN OFF Of the switches .It can be achieved near Zero Voltage switching and Zero Current Switching. The Snubber improves the slew rate by holding the voltage V_{b1} or V_{b2} which can also reduce the duty loss. This proposed topology can be applied to the renewable energy system using battery with high efficiency and also it can can yield the performance of lower voltage and current spikes and suitable for high power applications.

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