Isolated bidirectional full bridge dc-dc converter with fly back snubber

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Abstract - *An isolated bidirectional full-bridge dc–dc converter with high conversion ratio, high output power, and soft start-up capability is proposed in this paper. The use of a capacitor, a diode, and a flyback converter can clamp the voltage spike caused by the current difference between the current-fed inductor and leakage inductance of the isolation transformer, and also reduce the current flowing through the active switches at the current-fed side. Operational principle of the proposed converter is first described, and then, the design equation is derived. A 1.5-kW prototype with low-side voltage of 48 V and high-side voltage of 390 V has been implemented, from which experimental results have been verified with the help of MATLAB/SIMULINK*

***Key Words*: Flyback Converter, Isolated Full –Bridge Bidirectional Converter, Soft Start-Up.**

1.INTRODUCTION

IN RENEWABLE dc-supply systems, batteries are usually required to back-up power for electronic equipment. Their voltage levels are typically much lower than the dc-bus voltage. Bidirectional converters for charging/discharging the batteries are therefore required. For high-power applications, bridge-type bidirectional converters have become an important research topic over the past decade. For raising power level, a dual full-bridge configuration is usually adopted , and its low side and high side are typically configured with boost-type and buck-type topologies, respectively. The major concerns of these studies include reducing switching loss, reducing voltage and current stresses, and reducing conduction loss due to circulation current. A more severe issue is due to leakage inductance of the isolation transformer, which will result in high voltage spike during switching transition. Additionally, the current freewheeling due to the leakage inductance will increase conduction loss and reduce effective duty cycle. An alternative approach is to precharge the leakage inductance to raise its current level up to that of the current-fed inductor, which can reduce their current difference and, in turn, reduce voltage spike. However, since the current level varies with load condition, it is hard to tune the switching timing diagram to match these two currents. Thus, a passive or an active clamp circuit is still needed. An active commutation principle was published to control the current of leakage inductance; however, clamping circuits are additionally required. Passive and active clamping circuits have been proposed to suppress the voltage spikes due to the current difference between the current-fed inductor and leakage inductance of the isolation transformer .The simplest approach is employing an *RCD* passive snubber to clamp the voltage, and the energy absorbed in the clamping capacitor is dissipated on the resistor, thus resulting in lower efficiency. A buck converter was employed to replace an *RCD* passive snubber, but it still needs complex clamping circuits . A simple active clamping circuit was proposed , which suits for bidirectional converters. However, its resonant current increases the current stress on switches significantly. In Wang *et al.* proposed a topology to achieve soft-starting capability, but it is not suitable for step-down operation. This paper introduces a flyback snubber to recycle the absorbed energy in the clamping capacitor. The flyback snubber can be operated independently to regulate the voltage of the clamping capacitor; therefore, it can clamp the voltage to a desired level just slightly higher than the voltage across the low-side transformer winding. Since the current does not circulate through the full-bridge switches, their current stresses can be reduced dramatically under heavy-load condition, thus improving system reliability significantly.

2. CONFIGURATION AND OPERATION

The proposed isolated bidirectional full-bridge dc–dc converter with a flyback snubber is shown in Fig. 1. The converter is operated with two modes: buck mode and boost mode. Fig. 1 consists of a current-fed switch bridge, a flyback snubber at the low-voltage side, and a voltage-fed bridge at the high-voltage side. Inductor *Lm* performs output filtering when power flow from the high-voltage side to the batteries, which is denoted as a buck mode. On the other hand, it works in boost mode when power is transferred from the batteries to the high-voltage side. Furthermore, clamp branch capacitor *CC* and diode *DC* are used to absorb the current difference between current-fed inductor *Lm* and leakage inductance *Lll* and *Llh* of isolation transformer *Tx* during switching commutation. The flyback snubber can be independently controlled to regulate *VC* to the desired value, which is just slightly higher than *VAB*

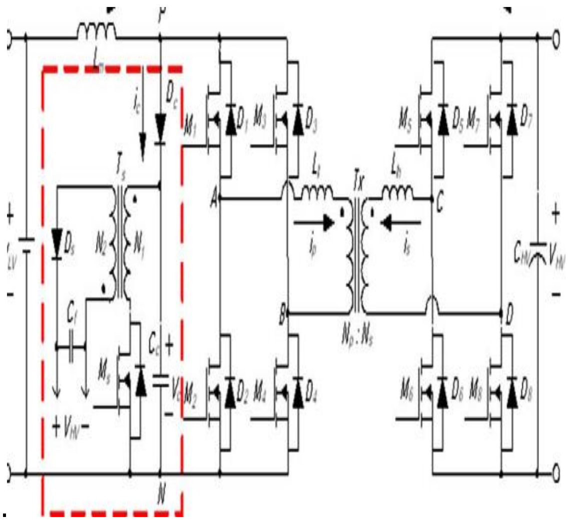

Fig. 1. Isolated bidirectional full-bridge dc–dc converter with a flyback snubber.

Thus, the voltage stress of switches $M1$–$M4$ can be limited to a low level. The major merits of the proposed converter configuration include no spike current circulating through the power switches and clamping the voltage across switches $M1$–$M4$, improving system reliability significantly. Note that high spike current can result in charge migration, over current density, and extra magnetic force, which will deteriorate in MOSFET carrier density, channel width, and wire bonding and, in turn, increase its conduction resistance. A bidirectional dc–dc converter has two types of conversions: step-up conversion (boost mode) and step-down conversion (buck mode). In boost mode, switches $M1$–$M4$ are controlled, and the body diodes of switches $M5$–$M8$ are used as a rectifier. In buck mode, switches $M5$–$M8$ are controlled, and the body diodes of switches $M1$–$M4$ operate as a rectifier. To simplify the steady-state analysis, several assumptions are made, which are as follows.

1) All components are ideal. The transformer is treated as an ideal transformer associated with leakage inductance.

2) Inductor Lm is large enough to keep current iL constant over a switching period.

3) Clamping capacitor CC is much larger than parasitic capacitance of switches $M1$–$M8$.

A. Step-Up Conversion

In boost mode, switches $M1$–$M4$ are operated like a boost converter, where switch pairs ($M1$, $M2$) and ($M3$, $M4$) are turned ON to store energy in Lm. At the high-voltage side, the body diodes of switches $M5$–$M8$ will conduct to transfer power to VHV . When switch pair ($M1$, $M2$) or ($M3$, $M4$) is switched to ($M1$, $M4$) or ($M2$, $M3$), the current difference iC (= $iL - ip$) will charge capacitor CC , and then, raise ip up to iL . The clamp branch is mainly used to limit the transient voltage imposed on the current-fed side switches. Moreover, the flyback converter can be controlled to charge the high-voltage-side capacitor to avoid over current. The clamp branch and the flyback snubber are activated during both start-up and regular boost operation modes. A nonphase-shift PWM is used to control the circuit to achieve smooth transition from start-up to regular boost operation mode.

B. Step-Down Conversion

In the analysis, leakage inductance of the transformer at the low-voltage side is reflected to the high-voltage side, This circuit is known as a phase-shift full bridge converter. In the step-down conversion, switches $M5$ $M8$ are operated like a buck converter, in which switch pairs ($M5$, $M8$) and ($M6$, $M7$) are alternately turned ON to transfer power from VHV to VLV . Switches $M1$–$M4$ are operated with synchronous switching to reduce conduction loss. For alleviating leakage inductance effect on voltage spike, switches $M5$–$M8$ are operated with phase-shift manner. Although, there is no need to absorb the current difference between iL and ip , capacitor CC can help to clamp the voltage ringing due to Leq equals ($Lll + Llh$ ($N2p/N2s$)) and parasitic capacitance of $M1$–$M4$.

3.THE PROPOSED BLOCK DIAGRAM

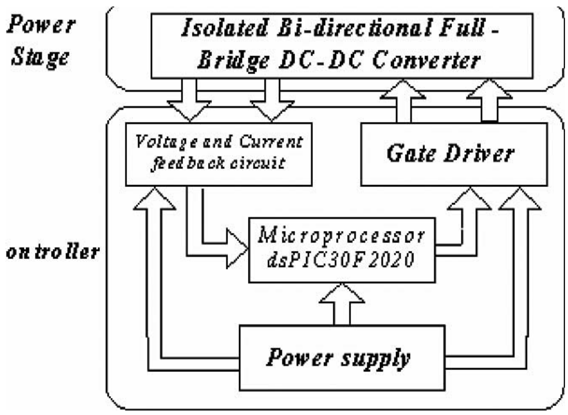

Fig. 2. Block diagram of the isolated bidirectional full-bridge dc–dc converter with the proposed flyback snubber.

A.Operation and working principle

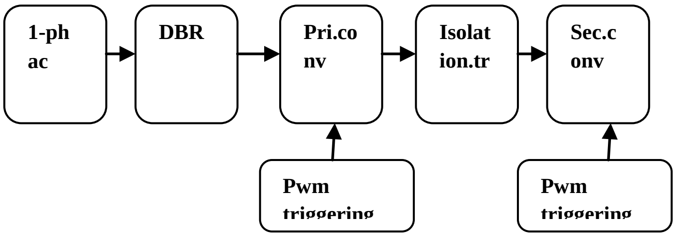

Fig. 3. Block diagram of the isolated bidirectional full-bridge dc–dc converter

A 1-ph AC supply is taken as input and is stepped down, converted in to suitable DC voltage from a diode bridge rectifier. The rectified DC is filtered out and fed as input to the main converter circuit in this project. This input DC could also be obtained from a batteries but as the cost of high power batteries is high, this stepdown transformer with DBR is employed. Now the input DC is converter to AC of high frequency through the action of MOSFET switching of primary flyback converter employing siutable PWM triggering. As this converter involves an isolation transformer which will draw high spiking currents to magnetize its core. This will lead to large voltage spikes at the switches and consequently damages the converter. To avoide this, this converter is equipped with an active snubber part which is a combination of inductor, diode & a capacitor to obsorb this voltage spikes. This obsorbed energy is again recycled and utilized at the secondary side to get large voltage gain.Secondary converter converters the HF AC from the isolation transformer to DC with high output to input conversion ratio.

4. PHOTOGRAPH OF THE PROTOTYPE CONVERTER

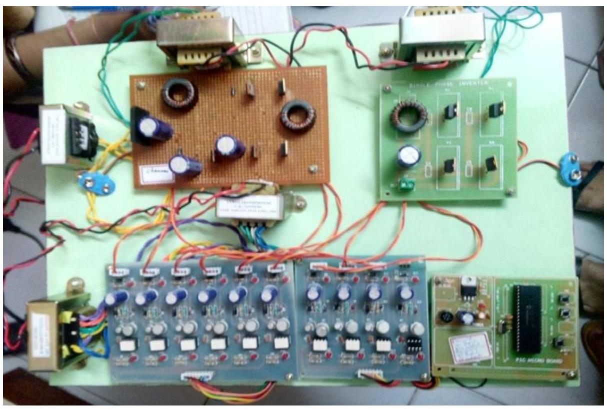

Fig 4. Prototype converter

5.SIMULATION RESULTS

A. I/O VOLTAGE WAVEFORM OF THE BOOST MODECONVERTER

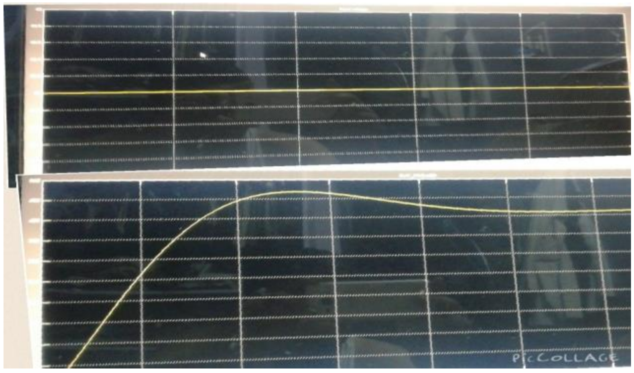

Fig.5.1. The output voltage boosted to 390V DC (shown in above fig)when the input voltage is 48V DC.

B. I/O VOLTAGE WAVEFORM OF THE BUCK MODE CONVERTER

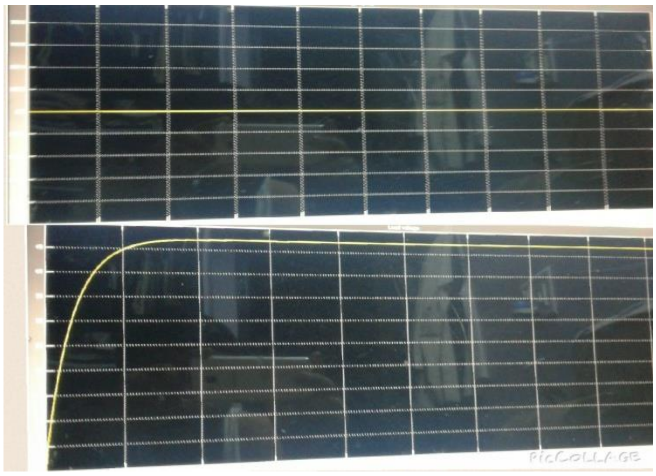

Fig.5.2. The output voltage bucked to 48V DC (shown in above fig)when the input voltage is 390V DC

6. CONCLUSION

This paper has presented an isolated bidirectional full-bridge dc–dc converter with a flyback snubber for high-power applications. The use of capacitor,a diode,and a flyback converter can clamp the voltage spike caused by the current difference between the current-fed inductor and leakage inductance of the isolation transformer, and can reduce the current flowing through the active switches at the current-fed side by 50%. This project introduces a flyback snubber to recycle the absorbed energy in the clamping capacitor. The flyback snubber can be operated independently to regulate the voltage of the clamping capacitor;therefore,it can clamp the voltage to a desired value. Since the current does not circulate through the full-bridge switches, their current stresses can be reduced dramatically under heavy-load condition, thus improving system reliability significantly. The flyback snubber can be also controlled to achieve a soft start-up feature. It has been successful in suppressing inrush current which is usually found in a boost-mode start-up transition.

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