A New Bi-directional DC-DC Converter for Fuel Cell Generation System

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Abstract: - In this paper, a new bi-directional dc-dc converter for fuel cell generation system is proposed to improve load response characteristic, because Fuel Cell has slow response characteristics for load variation. This bidirectional Converter interfaces the low voltage battery to the inverter dc link of fuel cell generation system. This converter works in boost mode when power flows from battery to high voltage side otherwise it works in buck. In this converter an active clamp snubber absorb the voltage surge across the turned off switched and also achieve the ZVS of all power switches during boost mode therefore it can operate at higher frequency, smaller size transformers and higher efficiency. The simulation results verify these advantages.

Key-Words: Bidirectional, dc-dc Converter, Fuel Cell, Active Clamp, PWM, ZVS

1 Introduction

A Fuel cell system is composed of five basic subsystems. The fuel cell stack, the fuel processor air and water management and power conditioning subsystem as shown in Figure1.Because of slow response in fuel cell, the power demand from load and the power supply from the fuel cell not match during a transient load thus we need a secondary source of energy to match the power difference between the fuel cell the in Figure2. If we use high voltage batteries for a long time, so the battery will be unstable. A 48V dc battery is used as a secondary energy source to supply transient load and the battery will compensate slow response of fuel cell. Recently some dc-dc converters with soft switching operation and isolated bidirectional operation have been developed. Isolated type topology applied to bidirectional dc–dc converters are divided into two basic types:

- Voltage fed converters
- Current fed converters

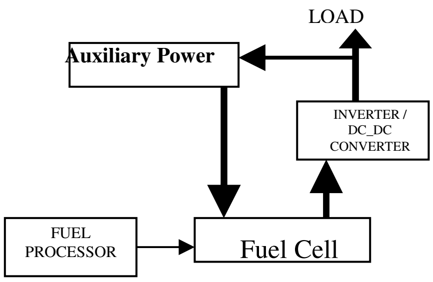

Fig.1- Block diagram of Fuel cell system

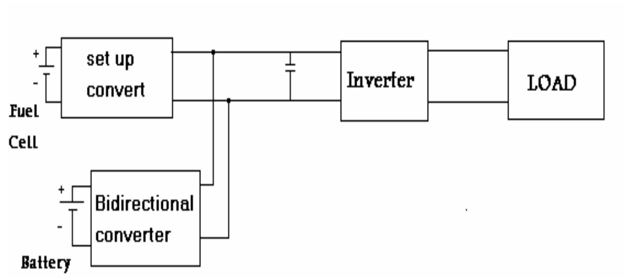

Fig.2- A Fuel cell system

In the voltage fed converters, turn ratio of high frequency transformer should be high because the boosting action is only performed by the turn ratio and therefore to the surge at turn off switching instants the enlarged snubber is required. Otherwise, in the current fed converter using an inductor in input cause the decrease of the current ripple and the inductor output filter can eliminate. Also an active boosting in action can cause the decrease of turn ratio in transformer each of those topologies can be a full bridge converter , half bridge converter or push pull circuit or their variations. The features of converter are presented in references [1]-[5].

Bidirectional dc-dc converters topologies for fuel cell application can be classified into three major groups .In the first group, in the primary there is a push pull current fed converter and in the secondary a half bridge voltage fed converter exists. Efficiency of this converter in the boosting mode is 90% approximately and in the buck mode is about 80%.from characteristics of this bi-directional converter is few device in its structure.

In the second group, in primary there exists a full bridge current fed converter with active clamp and in secondary a full bridge converter. the efficiency of this converter is higher than the converter in the first group(boosting mode 94%- buck mode 95%).Of the characteristics of this type is that it will be used in high power application and their switching is soft(ZVZCS).
The third group is similar to the first one but a forward converter is used instead of half bridge converter in secondary. Efficiency of this group is 80% approximately and it is used for medium power applications. Half bridge converters and push pull converters have many advantages such as few devices but there are some defects that are not applied into high power applications. Also push pull converter need careful design to avoid flux imbalance. Full bridge type needs more devices than other types but it can be used to high power applications. Three candidate topologies for boost mode full bridge converter of bi-directional dc-dc converter have shown in Table 1 [6].

Table 1-Various topology of full bridge converter

	Advantages	Disadvantage
Series/Parallel Resonant	Sinusoidal Current Soft Switching Low Ripple Current	Large Resonance Inductor High Voltage & Current Variable Ferequency Control
Active Clamp	Constant Frequency No Output Filter Inductance Soft Switching	Soft Switching may be lost at Light Load
Phase Shifted	Simple Control Constant Frequency	Output Diodes Hard Switched

In this paper, a medium power, active clamp current fed push pull converter using mosfets operates to discharge battery where as a voltage fed half bridge converter employing IGBT operates to charge he battery. The advantages of new bi-directional dc-dc converter are:
-The voltage across the switches is well clamp
-All switches operate under ZVS condition

2 Proposed bidirectional dc-dc converter

2.1 Discharge Operation (Boost Mode)

The proposed converter consists of an active clamp capacitor and two auxiliary switches (ma1, ma2). The main advantage of this auxiliary circuit is ZVS operation for all switches. This bi-directional

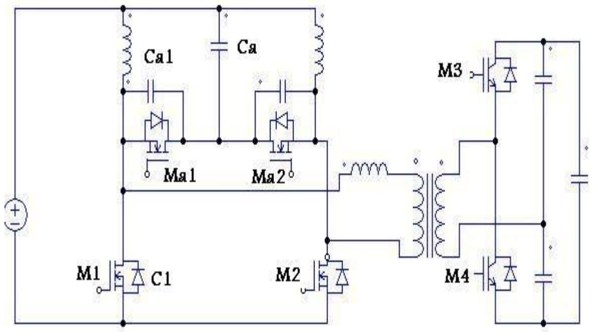

Fig.3-The Proposed Bidirectional Converter

converter is shown in Figure 3. The auxiliary switch Ma1 is turned on when the main switch M1 is off respectively. The timing diagram and main circuit waveform are shown in Figure 4.

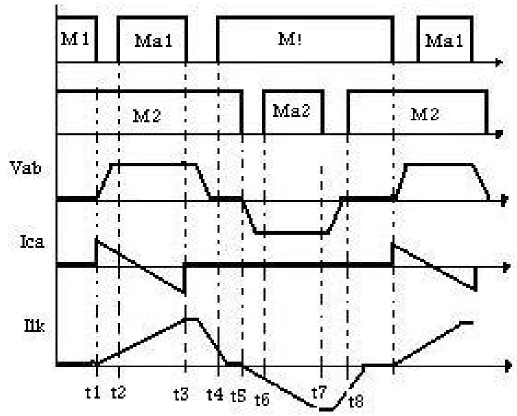

Fig.4- Timing diagram and main waveform converter at boost mode operation

This converter operates in four modes which are illustrated below:
Mode1: In this mode M1 is turned off . Iin beings to charge C1,Ca and discharge Ca1 linearly. After Iin Discharge Ca1 to 0, it flows through to anti parallel diode of switch Ma1.Therfore Ma1 can be turn on with ZVS at the next mode.
Mode2: When Ma1 is turned on, this mode being. In this mode leakage inductor current increase linearly and becomes larger than Iin after Ica become negative.
Mode3: This mode beings with turned off Ma1.leakage inductor current beings to charge Ca1 and discharge C1 to 0.Therfore M1 can be turned on in ZVS at next mode.
Mode4: When M1 is turned on this mode beings and leakage inductor current decrease to Iin linearly.

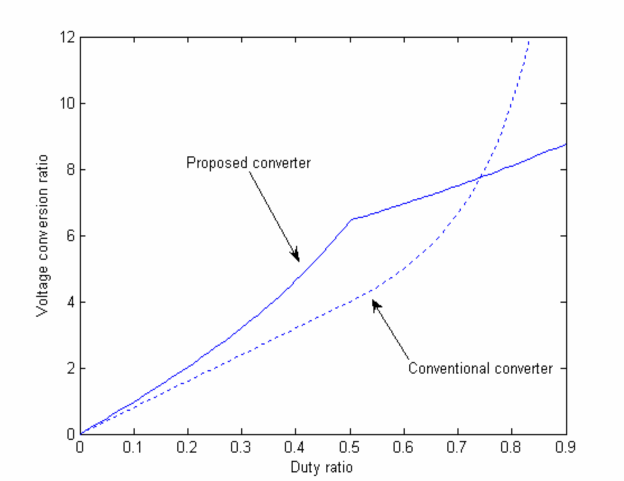

Fig.5- Comparison of the voltage conversation ratios between the proposed and conventional converter

2.2 Charge Operation (Buck Mode)

As shown in figure 2 a voltage fed half bridge converter for buck mode operation is used. In Figure 6 timing diagram of voltage fed half bridge converter at charge operation is shown.

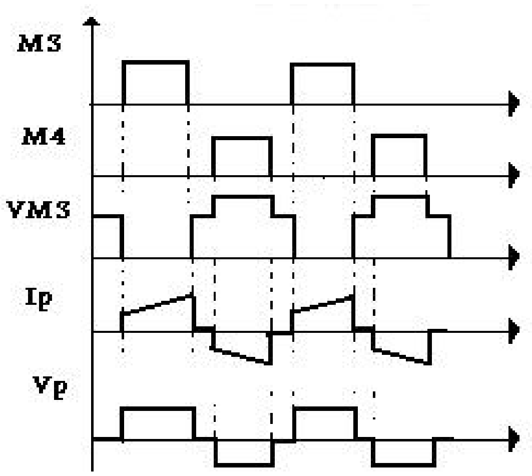

Fig.6- Timing diagram and main waveform of converter at buck mode operation

3 Simulation Results

The parameter of the bidirectional converter are shown in Table 2..

Table 2- The parameter of the bidirectional converter

Input Inductances	320uH
Clamp capacitance	3.5uF
Switching Frequency	50Khz
Transformer	1:3
Battery Voltage	48-55V
Output Voltage (Dc Bus)	380V
Leakage Inductance	13uH

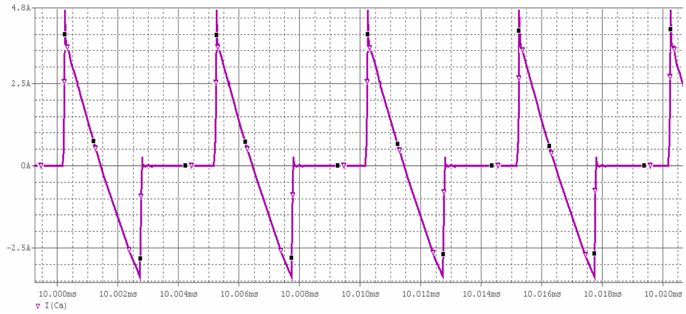

Fig 7- The Waveform of clamp capacitance current

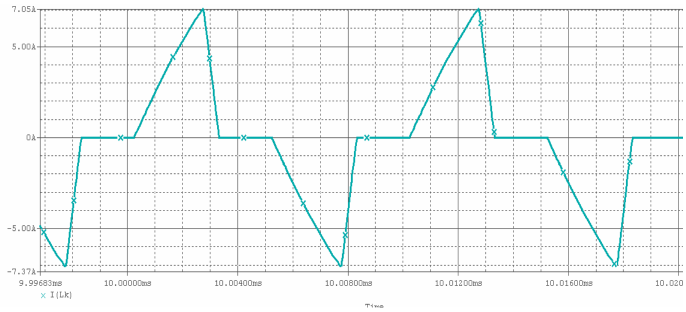

Fig.8- The Waveform of leakage inductive current

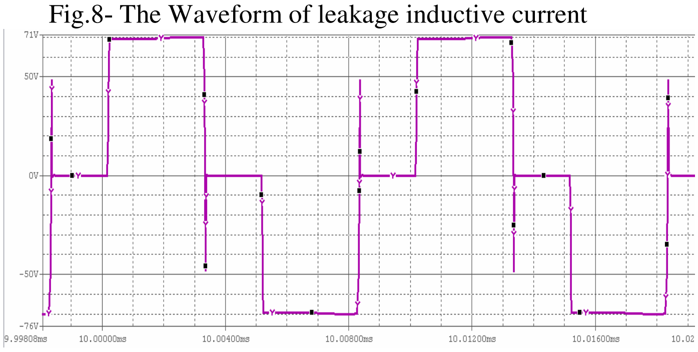

Fig 9- The Waveform of Transformer voltage

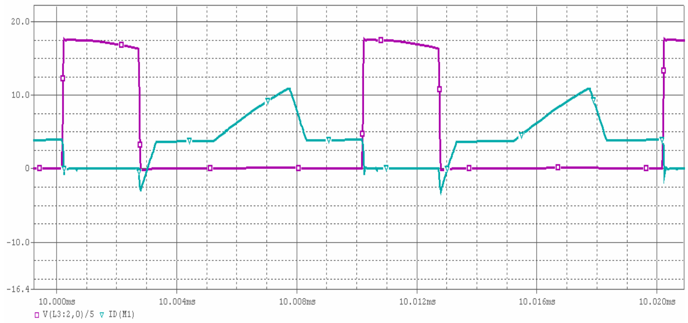

Fig 10- The Waveform of voltage & current of main switch

The main waveforms of converter are shown in Figure 7 to Figure 10. As seen all switches turn on under ZVS condition and turn off at almost ZVS

4 Conclusion

In this paper, circuit topologies of dc-dc converter with bi-directional power flow and with electrical isolation between the two sides through a transformer are evaluated for Fuel Cell application. A circuit configuration with the active clamp current fed push pull converter on the low voltage side and voltage fed half bridge converter on the high voltage side is proposed. These advantages are:

- The voltage across the switches is well clamp
- All switches operate under ZVS condition
- There is no voltage overshoot
- No ancillary snubbing is required

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