Reduction of Ripple in Bidirectional Dc-Dc Converter for Fuel Cell

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Abstract—This paper presents a reduction of ripple using π filter and c filter in bidirectional isolated dc-dc – dc converter. A typical application for this converter is battery charging for electrical vehicles, telecommunication and speed control of dc-motor. The advantages of the half bridge circuit with c filter are reduced ripple content present in the voltage and current waveforms, soft switching, low cost and high efficiency. The use of fuel cells is now envisaged to supply electrical energy in high power rail transportation application. The mat lab simulation results are compared with the experimental results.

Index Terms—Soft switching, microcontrollers, bidirectional dc-dc converters, half bridge converters

I. INTRODUCTION

Isolated bidirectional dc-dc converters are widely used in UPS battery charging and discharging systems. For such fuel cell energy system application functions of this dc-dc converter are two fold; first to boost the voltages for the filter motor drive [1]-[3].

This converter has the advantages of reduced ripple from 12V battery derived power to boost the high voltage bus up to 252V and second to store the content, reduced switching losses, improved EMI increased efficiency, High reliability and low cost. It is a good alternative to isolated boost full bridge dc-dc converter. The main objective is to reach high efficiency, high power density and cheap topology in a simple structure. Normally the voltage source converter has high current ripples, while a current source converter requires voltage clamp circuit [5]. This paper presents a bidirectional dc-dc converter. This converter is based on the dual half bridge with π filter topology, Compared to the full bridge topologies, it has reduced component count for the same power rating with no total power rating penalty. Zero voltage switching is applied in all the switches without any additional component. This circuit allows efficient power conversion, easy control, light weight and compact packing.

Active clamping technique has been an attractive choice due to ZVS for both the main switch and auxiliary switch [6]-[8]. However, most of the existing soft switched dc – dc converters are lower bidirectional [9]-[13].

This paper presents a open loop half bridge bidirectional

dc-dc converter with π filter simulation model in mat lab 7.5 version. The above literature does not deal with comparison of π filter and C- filter for the dc-dc converter. This work deals with reduction of ripple in bidirectional dc-dc converter

II. CONVERTER DESCRIPTION AND ANALYSIS

Fig 1 shows the half bridge bidirectional dc-dc converter. Fig 2 shows the soft switched bidirectional half bridge π filter with dc-dc

Converter. It contains five parts including a dc input circuit, a primary side circuit, a secondary side circuits a filter circuit and a dc output circuit.

Fig 1- soft switched bidirectional half-bridge dc-dc convertor

The major symbol representation is summarized as follows; V_{in} and L_{dc} are the input circuit parameters. They are input voltage and input inductor. Primary circuit has switches S_1, S_2 , C_{r1} , C_{r2} , C_1 and C_2 . Secondary circuit has S_3 and S_4 switches C_3 and C_4 Filter circuit are L_f filter inductor, C_{f1} and C_{f2} are filter capacitor. C_0 and V_0 are output capacitor and output voltage. The operation allows a resonant discharge of the lossless snubber capacitance of the switching devices and each devices antiparallel diode is conducted before the conduction of switching devices.

There are two modes

Mode: 1 Energy storing mode

Mode: 2 Energy transferring mode

Energy storing mode :

In the input side supply voltage is applied within the range of 12-15v with internal resistance of 1Ω . Energy is stored in the Inductor. Stored energy is released after some time interval. Time period is depend upon the switching frequency.

Energy transferring Mode:

To transfer the energy from Inductor to the entire circuit. The duty cycle ratio is 50% .

TABLE : 1 OUTPUT VOLTAGE WITH π FILTER

Factor 1	Factor 2	Factor 3	Factor 4	output
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A:Input Voltage volts	B:Filter Inductance microhenry	C:Filter Capacitance Micro Farad	D:Load Resistance Ohms	voltage in volts
20	1	100	10	45.28
20	2	90	20	54.02
20	3	80	30	58.07
20	4	70	40	60.39
24	1	100	10	54.56
24	2	90	20	65.08
24	3	80	30	69.95
24	4	70	40	72.75
28	1	100	10	63.83
28	2	90	20	76.13
28	3	80	30	81.84
28	4	70	40	85.11
32	1	100	10	73.11
32	2	90	20	87.19
32	3	80	30	93.72
32	4	70	40	97.47

TABLE : 2 C FILTER

Factor 1	Factor 2	Factor 3	output voltage in volts
A:Input Voltage volts	C:Filter Capacitance Micro Farad	D:Load Resistance Ohms	
20	100	10	44.28
20	90	20	53.02
20	80	30	57.07
20	70	40	59.60
24	100	10	53.54
24	90	20	64.65
24	80	30	68.69
24	70	40	71.72
28	100	10	62.63
28	90	20	75.13
28	80	30	80.84
28	70	40	84.80
32	100	10	72.21
32	90	20	86.49
32	80	30	92.93
32	70	40	96.97

From the Table 1 and Table 2 it can be seen that the π filter is superior to the C filter. The two parameters are input voltage and filter inductance are more significant than other parameters.

III. MATHEMATICAL ANALYSIS OF CIRCUITS

The section deals with calculation of DC – DC converter of ZVS-PWM. The calculation used to find out the output voltage control region of converters. The formula is utilized to be calculated the output voltage Losses:

1.The conduction losses in the rectifier are the same for conventional PWM and ZVS PWM.

$$P_{\text{rect}} = 4 (I_{\text{out}} / 2 V_f) \text{ -----(1)}$$

V_f is the forward drop for the rectifier diodes, assuming that a full bridge rectifier is used.

2. The conduction losses on the primary bridge diodes are.

$$P_D = V_{\text{diode}} I_{\text{av}} \text{ -----(2)}$$

V_{diode} is the forward voltage drop on the diodes and I_{av} is the average current.

3. The conduction losses due to channel resistance of the switches can be calculated as

$$P_Q = R_{\text{on}} I_{\text{rms}} \text{ -----(3)}$$

To find parameters.

$$1. L = V_o \delta / f \Delta I \text{ -----(4)}$$

$$2. I_o = V_o / R \text{ -----(5)}$$

$$3. P_o = V_o^2 / R \text{ -----(6)}$$

$$4. E_1 = 4.44 N_1 \Phi f \text{ -----(7)}$$

$$5. E_2 = 4.44 N_2 \Phi f \text{ -----(8)}$$

$$6. C = \delta / 2 f R \text{ -----(9)}$$

$$7. V_o = V_{\text{in}} \delta \text{ -----(10)}$$

$$8. V_o = \frac{V_{\text{in}}}{(1 - \delta)} \text{ -----(10)}$$

Total losses are 65 W approximately.

IV. SIMULATION RESULTS

The circuit model of boost converter is presented in the open loop with π filter. The Fig 4(a)shows that open loop Boost mode circuit diagram with motor load Input voltage of 24 volts and produce higher voltage in the output.

Fig 4(a) Boost Mode Circuit Diagram with π filter

Fig 4b Dc input voltage

The input voltage is 24 volts as shown in Fig.4(b)

Fig 4(c) Driving pulses

The Driving pulses is applied to the switches are shown in Fig.4(c.)

Fig 4(d) Switch-1 Vds and Vgs output

Fig 4e Switch-2 Vds and Vgs output

The switching output voltages across the drain to source and gate to source are shown in Fig 4(d) and 4(e)

Fig. 4(f) DC output current

The output current flowing in the circuit is 2.5A as shown in fig 4(f)

Fig 4(g) Armature speed

The motor runs at a speed of 700 rpm at 48 volts in the miniature motor as shown in Fig.4(g)

Fig 4(h) Torque

The Torque developed in the motor is 2.6 Nm as shown in Fig.4(h)

TABLE: 3

Circuit parameters	
Input voltage	24 volts
Output voltage	52 volts
Load resistance	100 Ohms
Switching frequency	55 KHz
Filter capacitance	70 μ F
Miniature motor	48 volts 1500 rpm

TABLE: 4

Ripple (Peak to Peak)		
Voltage	π filter	C filter
	0.04	0.42
Current	0.04	2

The comparison of π filter and C filter of voltage and current for the peak to peak ripple content are The comparison of π filter and C filter of voltage and current for the peak to peak ripple content are presented in the table 4. The power quality should be raised with the help of π filter. Boost mode circuit with c- filter Diagram is shown in fig 5(a) The input voltage 24V is applied in the circuit diagram is shown in fig 5(b). The inverter output voltage is shown in fig 5(c) The armature speed is similar speed of the π filter is shown in fig 5 (d). the torque is produced in the c-filter is shown in fig 5 (e). The combination of c-filter and π filter of ripple voltage in peak to peak are shown in fig 5(f) The combination of c-filter and π filter of ripple current in peak to peak are shown in fig 5(h)

Fig 5(a) Boost Mode Circuit with

c- filter Diagram

Fig 5(b) Dc input voltage

Fig 5(c) Inverter output

Fig 5(d) Armature speed

Fig 5(e) Torque

Fig 5(f) Ripple voltages of π filter and C filter

Fig 5(g) ripple current of π filter and C filter

Fig 5(h) Boost Mode DC Output Voltage
The boost mode c-filter

V. EXPERIMENTAL VERIFICATION

The hardware is fabricated and tested. The AT89C2051 is a low-voltage, high-performance CMOS 8-bit microcomputer with 2K Bytes of Flash programmable and erasable read only memory (PEROM). The device is manufactured using Atmel's high density nonvolatile memory technology and is compatible with the industry standard MCS-51™ instruction set. By combining a versatile 8-bit CPU with Flash on a monolithic chip, the Atmel AT89C2051 is a powerful microcomputer which provides a highly flexible and cost effective solution to many embedded control applications. A 1KW laboratory model of bidirectional DC to DC converter is fabricated and tested in the laboratory. Driving pulses required by the MOSFET are generated using 89C51. They are amplified by using driver amplifier. Top view of the hardware is shown in fig 6(a). The input DC voltage as shown in fig 6(b). Driving pulses are shown in fig 6(c). The inverter output voltage is shown in fig 6(d). The boost output voltage as shown in fig 6(e). The buck output voltage of 15v is shown in fig 6(f). The converter has a full load efficiency of 94%.

TABLE :5

Circuit Parameters	
M1 – M4	IRF530N
LDC	1.2 μ H
C1- C4	3.2nf
Transformer core	ETD 49
Transformer Ferrite grade	3C85
Cf	14.7 μ f
Miniature motor 1A Model 842	V=220V power 19W

Fig. 6(a) Photo of the proto type

Fig. 6(b) DC input voltage

Fig. 6(c) AC input voltage

Fig. 6(d) Driving pulses

Fig. 6(e) Inverter output voltage

Fig. 6(f) Boost output voltage

Fig. 6(g) Buck output voltage

TABLE : 6 VARIATION OF EFFICIENCY

output power(w)	efficiency
420	88%
610	90%
800	91%
915	94%

Fig. 6 (h) out put power Vs efficiency

VI. CONCLUSION

The conventional half bridge bidirectional dc-dc converters have low power quality. π filter reduces the ripple content and increases the efficiency. The input voltage and filter inductance are selected to reduce the harmonic content below 5%. The efficiency is 94%. The experimental results closely agree with the simulation results.

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Fig 2 - soft switched bidirectional half-bridge pi filter with dc-dc converter