

DESIGN AND SIMULATION OF A SOFT SWITCHED INTERLEAVED FLYBACK CONVERTER FOR FUEL CELLS

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Abstract

This paper presents a soft switched interleaved fly back converter for fuel cell systems. The proposed topology consists of a three stage fly back converter with three transformers. Because of interleaved operation of converter, the output current ripple will be reduced. The proposed converter can approximately share the total load current between the two secondaries. Therefore, the transformer copper loss and rectifier diode conduction loss can be decreased. Moreover, it is based on zero voltage switching technique in which switching takes place when the voltage wave attains zero thus reducing the switching losses. This improves the overall efficiency of the converter. Detailed analysis has been done to investigate the benefits of interleaved flyback converter compared to the conventional interleaved boost converter. Simulation study for the Interleaved Flyback Converter and IBC has been studied using MATLAB/SIMULINK. Hardware prototype is built to validate the results.

Keywords : Interleaved Flyback converter, soft switching, ripple & losses

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1. INTRODUCTION

In recent years, lower output voltage, higher power-densities, faster transient response and higher current have become very important topics for the telecom power supplies. Flyback converters are widely applied on electrical power-supply circuits with low-power demand and low component counts. It has high efficiency and low cost. The transformer in the flyback converter is used to isolate the electric signal and store the magnetic energy[1,2]. The limited power-handling capability is imputed to this converter's buck–boost-based behavior. This paper focuses on the basic operation of a three phase Interleaved flyback Converter, soft switching techniques and calculation of switching losses. Also, the design aspects of IBC have been presented. Simulation studies have been performed using SIMULINK and hardware prototype has been built to validate the results.

2. INTERLEAVED FLYBACK CONVERTER

Flyback converters are attractive candidates for low power isolated voltage regulation applications due to their relative simplicity compared with other topologies [3,4]. In order to raise the efficiency of the proposed converter, a 3-phase interleaved flyback converter integrated with soft switching cells is used. All of the switching devices in the proposed converter achieve zero voltage switching (ZVS). Thus, the proposed circuit as shown in Figure 3.2 has a high efficiency characteristic due to low switching losses. The proposed converter can reduce the switching loss because the switches are turned on and off with zero voltage switching (ZVS). The proposed converter has the advantages of both the interleaving topology and soft switching. It can reduce the switching loss because the switches are turned on and off with zero voltage switching (ZVS) as well as implements interleaving technique. The circuit diagram of three phase interleaved flyback converter is shown in Fig.1.

2.1. Design Considerations

Flyback converter components must be selected that can handle the necessary current and voltage stresses [5,6]. All of these stresses are transformer related: turns ratio and inductance. Thus the key component and design issue in the converter design is the flyback power transformer which acts as a coupled inductor. A design always starts with design specifications, including the input voltage range, power level and output voltage.

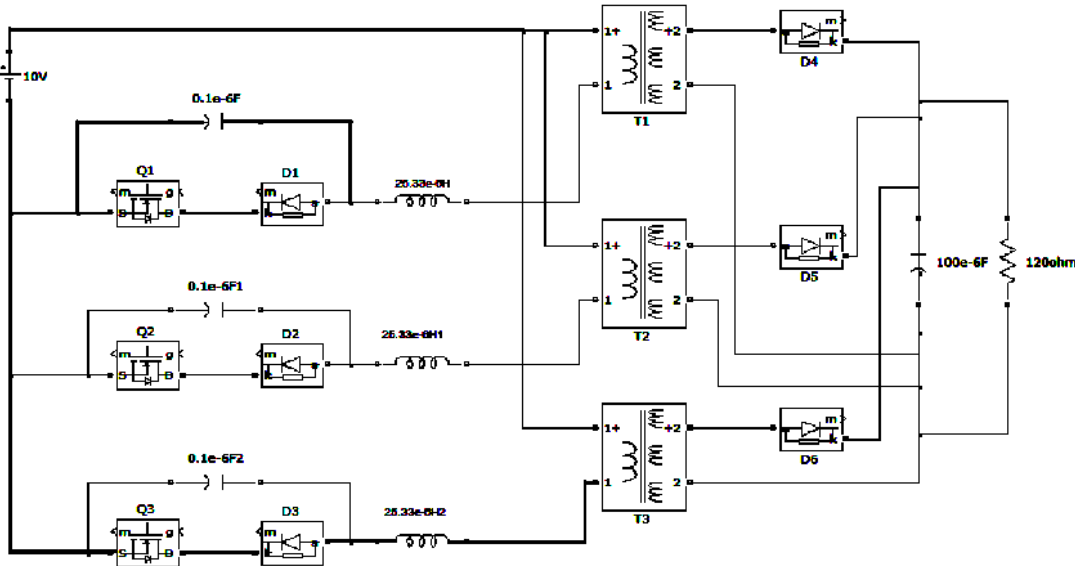


Figure .1 Soft switch based Interleaved flyback converter

The duty cycle and switching frequency are normally predetermined. The design procedure is as follows :

2.1.1 Selection of Flyback Transformer

The high inductance is needed to keep operation in continuous conduction mode over a wider load range. With higher inductance, the ripple currents in both the primary and secondary circuit will be lower [7,8]. The turns ratio for the transformer is determined using the equation 1.

$$M = V_o/V_{in} = 1/n(1 - D) \tag{1}$$

where M is the turns ratio, Vo is output voltage, Vin is input voltage, n is the number of phases and D is the duty ratio.

2.1.2 Selection of Power Devices

Power diodes are used for lower cut-in voltage, higher reverse leakage current, higher operating frequency. MOSFET is used as a switching device since it is a voltage controlled device, having high gate circuit impedance. Since it has positive temperature coefficient, secondary breakdown does not occur.

2.1.3 Choosing Number of Phases

This paper utilizes three phases since the ripple content reduces with increase in the number of phases. But if the number of the phases is increased further, without much decrease in the ripple content, the complexity of the circuit increases very much, thereby increasing the cost of implementation. Hence, as a tradeoff between the ripple content and the cost and complexity, number of phases is chosen as three. The gating pulses of the switches of the two phases are shifted by $360/n$, i.e., $360/3$ for $n=3$, which is 120 degrees.

2.1.4 Selection of Capacitance

The selection of capacitance is one using equation -2. Due to the interleaved operation, the capacitor C_o is replenished twice in a switching period.

$$\Delta V_C = \frac{I_o D_{eff}^2 T_S}{2C_o} = \frac{V_o D_{eff}^2 T_S}{2R_L C_o} \quad (2)$$

Where D_{eff} represents effective duty ratio, T_s represents switching period, C_o represents the output capacitance, R_L represents load resistance, V_o represents the output voltage and ΔV_C represents the capacitor voltage.

3. SIMULATION RESULTS

The simulation of three phase interleaved flyback converter is done in MATLAB/SIMULINK and using the parameters given in Table .1. The results obtained are shown in Figs.2 -4

Table. 1 Simulation Parameters

Parameters	Values
Input voltage	10V
Output voltage	42V

Switching frequency	20kHz
Resonant Frequency	100kHz
Capacitance	0.1uF
Inductance, L	25.33uH
Resistive Load, Ro	120 Ohms
Filter Capacitor	100uF

Figure .2 illustrates the input current from which the input current ripple is calculated.

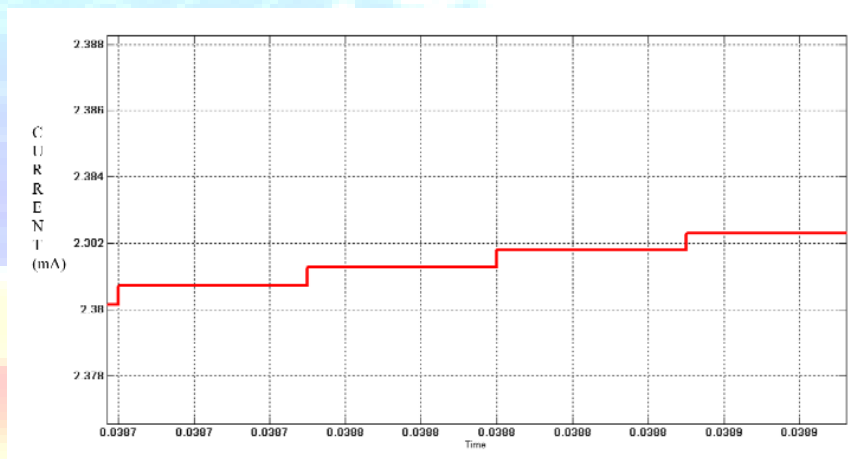


Fig.2.Input Current of Interleaved Flyback Converter

Figure 3 illustrates the output current from which the output current ripple is calculated.

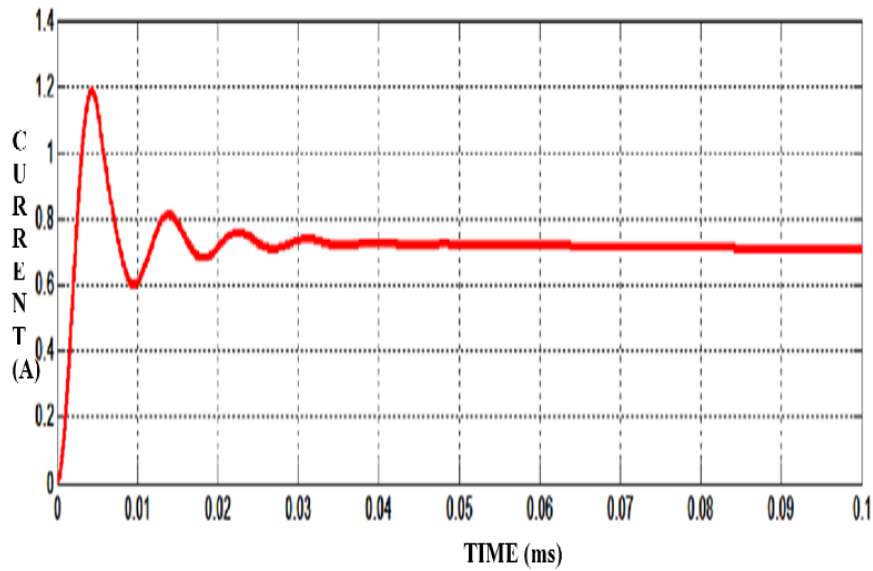


Fig.3 Output Current of Interleaved Flyback Converter

Figure 4 illustrates the output voltage from which the output voltage ripple is calculated. The output voltage is obtained as 42V.

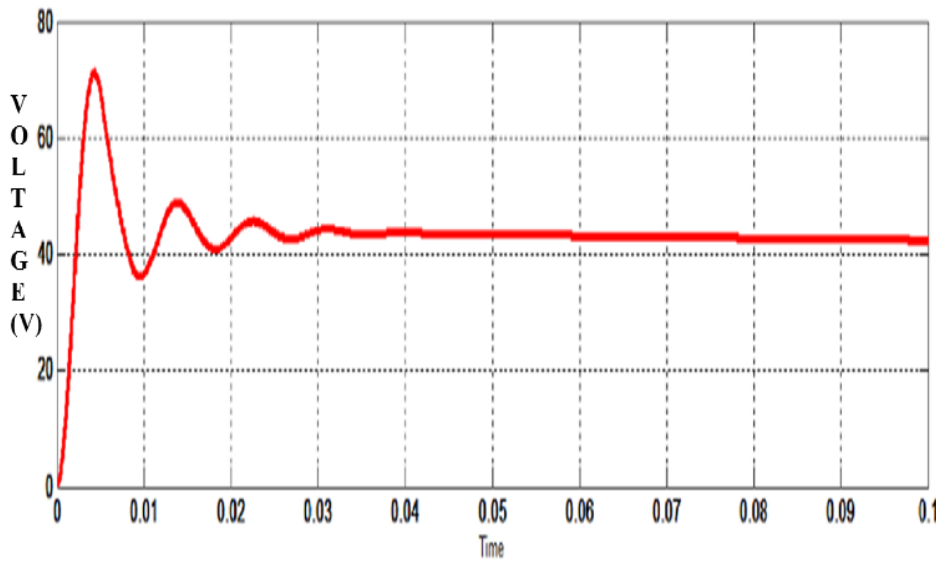


Fig.4 Output Voltage of Interleaved Flyback Converter

From Fig.4, it is clear that the output settles at the desired value of 42V. The input current ripple and output voltage ripple has been calculated for the proposed flyback converter and its result are compared with the conventional IBC. It is found that soft switched flyback IBC gives a reduced ripple compared to the conventional one as shown in Table –II.

TABLE –II Comparison of Performance Parameters

Performance parameters	Conventional phase IBC	Two-	Soft switched Flyback IBC
Input Current Ripple (A)	1.4 X10 ⁻³		6.488 X 10 ⁻⁴
Output Current Ripple (A)	2.04 X 10 ⁻³		6.964 X 10 ⁻⁴
Output voltage Ripple (V)	1.76 X 10 ⁻³		9.2433 X 10 ⁻⁴

The equations governing the calculation of conduction loss for a MOSFET is given below [9-11]:

$$P_{COND(FET)} = I_{drain(rms)}^2 \times (R_{DS(ON)} \times 1.5) \quad (3)$$

where I_{drain} is the root-mean-square (rms) value of the drain current, R_{DS} is the resistance of MOSFET as given in datasheet. I_{drain} is calculated from the MOSFET drain current waveform. The formula is given as:

$$I_{Drain(rms)}^2 = (I_0^2 + I_1^2 + I_0 I_1)/3 \times (t_{a1}/T) + (I_2^2 + I_3^2 + I_2 I_3)/3 \times (t_{b1}/T) + (I_3^2 + I_4^2 + I_3 I_4)/3 \times (t_{c1}/T)$$

(4)

Using equation (3&4), the conduction loss is found to be 4.749W. The transient characteristics of power MOSFET is observed and the switching loss is estimated as 4.6 mW which is low due to soft switching.

4. EXPERIMENTAL RESULTS

A prototype of three-phase soft switched IBC was built using power MOSFET and the pulses were generated using PIC microcontroller as shown in Fig.5.



Fig.5. Gating Pulse Pattern for MOSFET

Figure 6 illustrates the output voltage of 40V for an input of 10V .

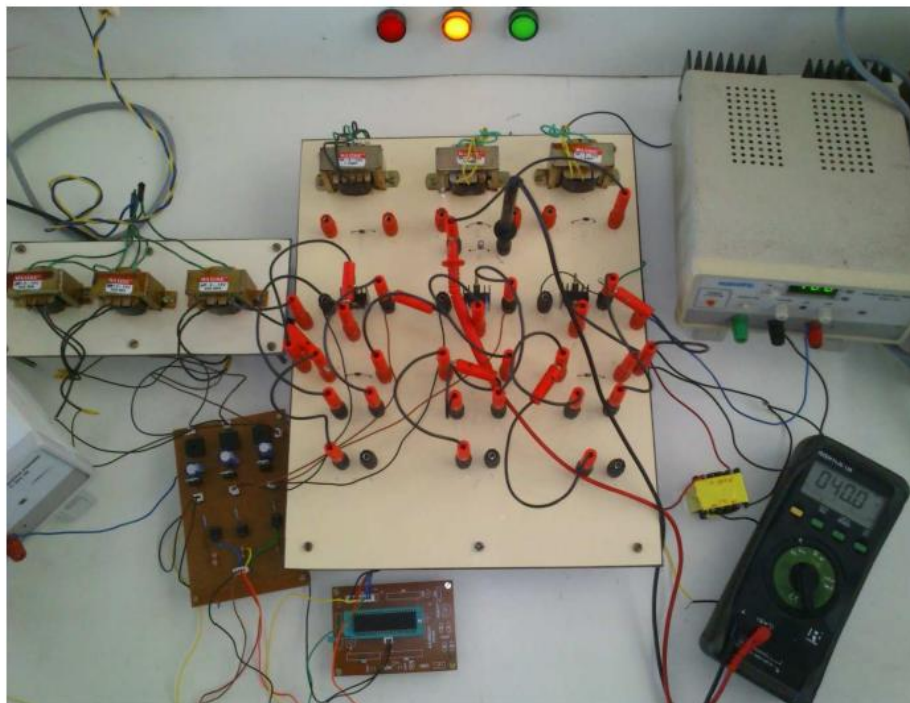


Fig.6 Prototype of soft switched IBC with an output of 40V

The results from the hardware implementation closely matched that of the simulated output.

5. CONCLUSION

A three-phase soft switched interleaved flyback converter has been presented. The performance parameters of the proposed converter have been investigated and it is found that it gives a reduced input current ripple and output voltage ripple compared to the classical IBC. Experimental work for the proposed converter has been carried out and the results are closely matching the simulation. Therefore, with reduced ripples and less switching losses, soft switched flyback converter is a suitable choice for fuel cell applications.

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