

## Quasi Switched Capacitor based integrated Boost Series Parallel Fly-back Converter for energy Storage Applications

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A quasi-Switched Capacitor technique (QSC) is used to control the switch in Interconnected Boost Series Parallel Fly-Back Converter (IBSPFC). The QSC based IBSPFC does not require any snubber circuits for all the MOSFET switches presented at primary and secondary side and power can also be transferred even if one the winding gets damage. The primary side winding of the fly-back transformer is coupled in series across with bulk capacitor to minimize switch voltage stress and the secondary winding of the 1:1 fly-back transformer is coupled with dc voltage source, three switches and capacitor which forms a Quasi switched capacitor technique. Working techniques of quasi-switched capacitor with IBSPFC have been introduced. A 75v input, 100v output and DC-DC isolated Converter switching at frequency of 100 kHz is modeled using FPGA SPARTAN6LX9 and experimental results have been presented.

**Keywords:** Quasi Switched Capacitor (QSC), Fly-Back Converter, Boost converter, IBSPFC

### Introduction

At Present tendency, solar energy is attracting one of the well-organized resources in the area of renewable energy. As solar energy is freely available in the nature at free of cost helps to create a lot of electricity for residential, industrial, domestic, household purpose. As Solar, energy is obtainable universally the employment of solar panels to create electricity is helpful to produce electrify in rural areas. No translation devices is produces sins of disposal of direct dc current from solar energy. Series parallel dc-dc converter is an interconnected converter and module scheme suggested due to justification of solar power system because of advantages of low power handling capability and less time and lowcost installation. Compare to two stage transformation single stage Transformation is more well-organized not only due to less cost less preservation but can operate in both continuous and discontinuous mode<sup>1-3</sup>. Though high switch current in discontinuous mode make it advantages than two stage transformation.

### Interconnected boost - series Fly- back convertor (IBSPFC)

In IBSPFC with quasi switch converter (QSC) has been suggested<sup>4-5</sup>. The connects IBSPFC on primary

side and QSC on secondary side of transformer. The advantage of QSC is the soft switching technique used by the convertor help to improve the overall efficiency of the isolated quasi switched capacitor dc-dc converter and the MOSFET switch handles currents of both inductor in boost converter and fly-back circuit simultaneously. Here the advantage of both the converter is utilized to increase the capability of the converter<sup>6-8</sup>. The research study along with experimental results of IBSPFC with QSC is presented in this paper for closed loop control<sup>9-11</sup>. The design considerations for inductor in boost circuit, quasi switched capacitor and output capacitor are evaluated<sup>12-13</sup>. This presents design of QSC based IBSPFC operating at 100 kHz with DC input voltage magnitude of 25V on primary side, producing 50V and 100V at secondary side and at load with 100W of output power.

### Working Methods of QSC based IBSPFC

The circuit diagram for IBSPFC is shown in Figure.1(a) and the corresponding equivalent circuits working under two various modes of operations are presented in Figure. 1(b&c). The pulse waveforms of switches and the respective current waveforms are shown in Figure. 1(d). In mode 1 [ $0 < t < t_1$ ; Figure. 1(b)]: When the switches  $S_1$ ,  $S_2$ ,  $S_3$  are in ON condition. The current starts flowing through primary ( $V_{in}$ -L- $S_1$ )

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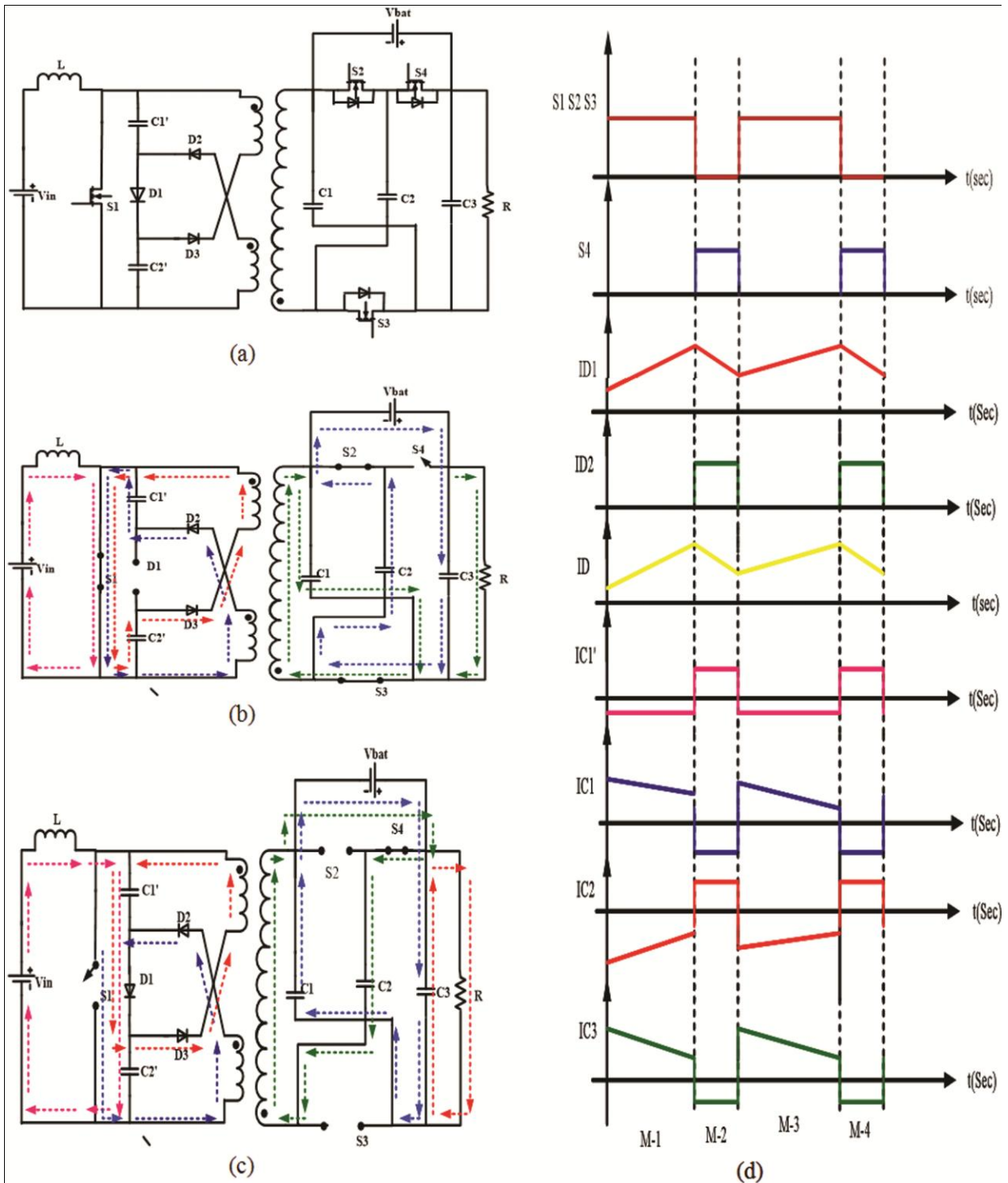


Fig.1 — Interconnected Boost parallel Fly-back Converter.(a)circuit, (b) mode1, (c) mode-2 and (d) corresponding wave form

Therefore the boost inductor current starts increasing. Capacitor  $C_1, C_2$  will be discharging through  $(C_1, S_1, D_2)$  &  $(C_2, D_3, S_1)$  and supplied to load<sup>7</sup>. On secondary side  $C_1, C_3$  will be charging and  $C_2$  will be discharging through  $(C_2, S_2, V_{batt}, C_3, S_3, C_2)$ . In mode 2  $[t_1 < t < t_2$ :

Figure.1(c)] the switch  $S_1, S_2, S_3$  are switched off and  $S_4$  switched on. In this mode of operation, the current flows through the path of  $+V_{in} - L - C_1 - D_1 - C_2 - (-V_{in})$ . In this mode, the discharging of boost inductor takes place through the capacitors and diode  $D_2$  and on

secondary side capacitor  $C_1, C_3$  are discharging and  $C_2$  is charging through  $-C_2 - V_{\text{batt}} - S_4 - (+C_2)$ .

**Soft Switching Analysis**

The output side three Switches are realized soft switching at on state transient. Since the departed time linking the managed signals of  $S_2, S_3, S_4$ . The diodes across the switching are not conduct therefore diodes conduction losses are nil. Switch  $S_2, S_3$  drain and source terminals adding minor Capacitor, gradually the voltage across the switch during the off momentary, the drain to source voltage built up to the fixed condition rate after the switch current is reduce to zero. The switches  $S_1, S_2, S_3$  are off condition ZVS isrealized<sup>13</sup>. Output side circuit battery to load power transferring directly. Soft Switching Analysis using in this circuit humanizing good organization and through double input maneuver.

**Mathematical Calculations**

Mathematical calculations is obtained for the QSC based IBSPFC. Design specifications are  $V_s=25V, V_o=100V, I_o=1A, R=100\Omega, f_s=100KHz, P_o=100W, V_B=50V$  and Battery=50V. The design calculations for QSC based IBSPFC are presented below based on the assumption that primary side source and secondary side battery will share total load.

**Boost converter Output Voltage and Inductor Current**

The boost output voltage ( $V_B$ ) of a boost converter is given by the expression  $V_s / (1-D)$ . In the above equation,  $V_s$  represents input voltage of magnitude 25V and  $D$  represents the duty cycle of value 0.5. Upon substituting these values, the boost output voltage is equal to 50V. Similarly, the expression for Inductor current ( $I_L$ ) is given by  $I_o / (1-D)$  where the term  $I_o$  represents output current. The magnitude of inductor current is equal to 2A for  $I_o = 1A$  and  $D = 0.5$ .

**Boost Inductance**

The value of inductor used in boost converter is obtained by using the following equation:

$$L_B = \frac{V_B D}{f_s \Delta I} \quad \dots (1)$$

Where  $f_s$  represents the switching frequency of value 100Hz and  $\Delta I$  represents the current ripple and is taken as 0.05A. The value of boost inductor is equal to 3.5mH upon the substituting the above values.

**Boost Capacitance**

The value of boost capacitance is obtained by using the equation:

$$C_B = \frac{D}{2f_s R} \quad \dots (2)$$

Where  $R$  represents the load resistance of value 100ohms. Upon substituting the values the boost capacitance value is equal to 25nF. An approximate value of 100µF is taken for practical case.

**Filter Inductance**

From the Fly-back Converter, to obtain the value of filter inductance ( $L_F$ ) the following equation is used:

$$P = \frac{V_B^2 D^2}{2L_F f_s} \quad \dots (3)$$

Where  $P_o$  represents the output power which is taken as 100w. The value of filter inductance is equal to 31.25µH. An approximate value of 40 to 50µH is chosen for practical case.

**Secondary side Capacitances**

The values of capacitances used on the secondary side are taken as  $C_1 = C_2 = C_3 = 100\mu F$ . The magnitude of voltage across capacitors during mode I and mode II are obtained as given below: During Mode I the voltage across capacitor  $C_1$  is equal to secondary winding voltage i.e.,  $V_{C1} = V_{\text{Secondary}} = 50V$ . The voltage across capacitor  $C_3$  is equal to output voltage i.e.,  $V_{C3} = V_o = 100V$ . And the voltage across capacitor  $C_2$  is equal to the difference between the voltages of capacitor  $C_3$  and battery ( $V_{\text{Bat}}$ ). The value is equal to 50V. During Mode II the voltage across capacitor  $C_3$  is equal to the sum of the voltages across capacitor  $C_2$  and battery ( $V_{\text{Bat}}$ ) which is equal to 100V.

**Voltage across the Switches**

During mode-I, the switch  $S_4$  is in off condition and the remaining switches  $S_1$  to  $S_3$  are in ON condition. The voltage which appears across  $S_4$  switch is equal to battery voltage which is equal to 50V. During mode-II the switch  $S_4$  is turned on and the switches  $S_1, S_2$  and  $S_3$  are turned off. The voltages which appears across these switches are given by the as:  $V_{s4} = V_{\text{Bat}} = 50V, V_{s2} = V_{\text{Bat}} = 50V; V_{s3} = V_{c3} - V_{c2} = 50V$

**Experimental Results**

The experimental results of QSC based IBSPFC with voltage mode control using FPGA are obtained. Figure 2(a) shows experimental setup of QSC based IBSPFC; Figure 2(b) shows the Switch S2

Zero Voltage, Zero Current and PWM Pulse, Figure 2(c) Switch S3 Zero Voltage, Zero Current and PWM Pulse, 2(d) Switch S4 Zero Voltage, Zero Current and PWM Pulse. Figure. 2(e) shows Output Current1A. Figure 2(f) shows Output Voltage100V.

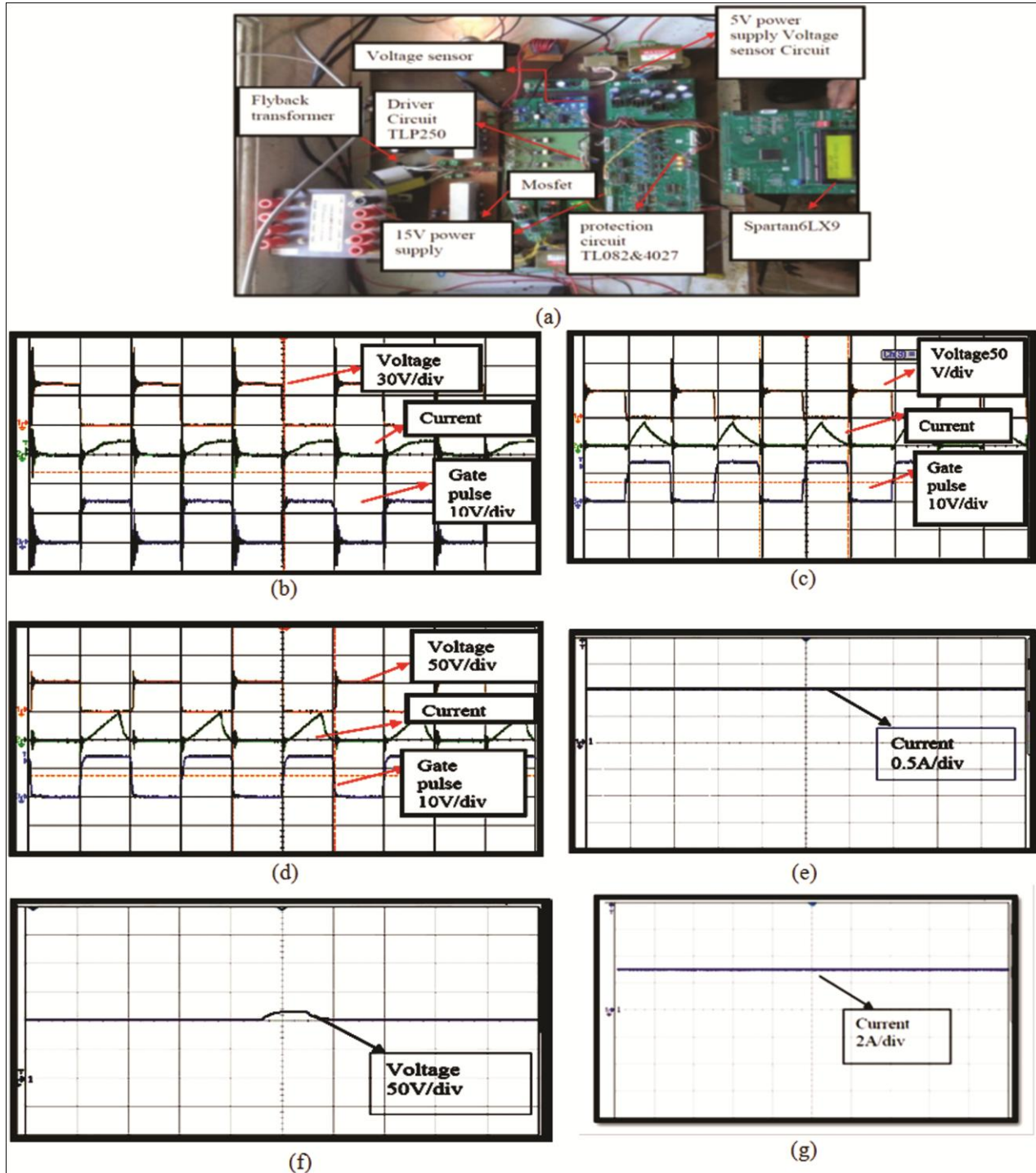


Fig.2 — (a) Home Based kit IBPFC with QSC,(b) Switch S2 Zero Voltage , Current, Pulse, (c) Switch S3 Zero Voltage, Current ,Pulse, (d) Switch S4 Zero Voltage, Current, Pulse, (e) Output Current1A, (f) Output Voltage100V,(g) Battery input Current0.7A

Figure 2(h) shows the secondary side battery input current 0.7A.

Table 1 — Hardware parameters for QSC based IBSPFC

Name	Number	Rating
Inductor	100 KHz, 3.5mH	10A
MOSFET	K2611,Toshiba	900v, 9A
Diode	MUR3060	600V, 30A
Capacitor (Primary)		63V, 100 $\mu$ F
Capacitor (Secondary)		100 $\mu$ F, 100V
Transformer (Ratio)		1:1 50V/50V
Transformer Inductance		45 $\mu$ H
Protection Circuit	TL082&4027	
FPGA	SPARTRAN6LX9	

## Conclusion

This paper presents analysis and working methods of QSC based IBSPFC. With this proposed connection of boost converter and fly back converter, the observations made are low switch current stress, tight voltage regulation with which the efficiency is improved. For the various input voltage levels of 25V, 75V and 100V the simulation part is done for the developed proto type which produces an output power of 100w at switching frequency of 100KHz. The converter has the ability to operate at 200w also. The applications of this developed model are battery charging and series connection LED drives etc. With the combination of IBSPFC with QSC, the efficiency of the convertor increases that i.e. 91% and because of soft switching used in QSC helps to increase overall converter efficiency. The future scope of this converter is to improve the power factor of the converter and maximum power point tracking by using different algorithms.

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