Integrated Buck Boost Series Parallel Fly-Back Converter for Electronic Ballast and LED Drive Applications

Naga Pooja V, Pandu Kumar K, Sravan Kumar S L V, Lokeswararao K

Abstract— Integrated Buck Boost Series Parallel Fly-Back Converter (IBBSPFC) a single MOSFET Switch is used. This IBBSPFC can achieve high or low voltages by buck and boost process. The pass through a filter capacitances be able to be low thus to facilitate film capacitor can be used. Buck-boost converter can operate in Buck mode and Boost mode with continuous conduction mode by the inductor and capacitors. In this design, regulation and reliability of the converter improves when the capacitors are linked in series among the main winding of isolation transformer and the power transfer capability is improved by parallel connection of the isolation transformer with capacitor. By this IBBSPFC can increase and decrease of volt conversion without any transformer losses is obtained for different duty cycles. Therefore, this is beneficial for higher efficiency and reliability and the cost of the System can be reduced by using Fast recovery diodes, inductor and capacitors. By Conversion of 24V input to 50VOutput in continuous conduction mode (CCM) under 100W output power is obtained.

Keywords: Integrated Buck Boost Series Parallel Fly- back Converter (IBBSPFC), Isolation Transformer, Continuous Conduction Mode (CCM), Open Loop Control, Buck-Boost Converter (BBC), Fly-back Converter (FC).

I. INTRODUCTION

Green power systems like Solar PV module and gas cells, are extensively used in industries & mobile home areas designed for reducing of carbon emission. But, small amount of end power is their typical defect [1]. In grid-tied usage, DC input voltage of a converter have to be high abundant to infuse power to utility grid [2]. For switching mode power supplies (SMPS) it requires high efficiency and more power density with high switching frequency can reduce the size of the power converters.

In Isolated DC-DC Converter FC is considered with BB regulator. Whereas Buck and Boost converters are used in power converters to increase or decrease the voltage obtained at the output, Buck operates as step–down chopper and Boost operates as step–up chopper. In most of the PV cells we required to get more voltage. By using the buck-boost converter the voltage can be given to the inverter as it takes

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low or high voltage [3]. Buck–Boost converter is a non isolated converter and whereas fly-back converter is a isolated regulator. In BB regulator the voltage at output side is more / low than the voltage at the supply side [4], applications are use in SMPS, [6] power amplifier and in battery power systems. The advantage of low operating duty cycle and higher output voltage. FC is taken as of the BB regulator as in BBC we use inductor coil (L), so this inductor is splited to form as the isolated transformer. Fly-back converter has a particular propose to facilitate it is a not direct converter that it does not have a direct path between input and the output in any instant of operation [7]. Applications of fly-back transformer are it develops high voltage, can fix multiple outputs and has low switching stress [5]. IBBSPFC is connected in series parallel with the isolation transformer, with it is linked in parallel it increases the reliability when one transformer is faulted then other transformer can operate and when it is connected is series it improves connecting two transformers in the input side can operate with the high power transfer capability. These fly back transformers can be used in Aeronautical applications, electrical converters and inverters.

In this propose, of the integrated buck boost series parallel fly-back converter a single switch is used this can reduce switching stress with one switch. Buck boost inductor is used at the input side [8], whereas the fly-back inductor acts as isolated transformer it is connected across the capacitors, the capacitor used can be a film capacitor as it use a slight plastic film as the dielectric. These film capacitances are low-priced, steady and can with stand for large reactive power values. These film capacitors are used in electronic ballast, X-ray flashes and can be used in snubber capacitors [6].

It has Single power switch, three capacitors, one inductor, seven diodes and isolation transformer are the main components of this converter. The inductor is at the supply side so it has the voltage same as the supply voltage. The study and representation of the suggested converter or circuit configuration is shown in Section 2. Mathematical calculations are in Section 3. The MATLAB Simulated results are in part 4 and conclusions are shown in part 5.

II. CIRCUIT CONFIFURATION

Circuit diagram of IBBSPFC has given in Fig. 1. With an Inductor, a single lever, two capacitors and six diodes at the input side with the isolation transformer; the output part of the isolation transformer is connected to R load with a Diode and the capacitor.
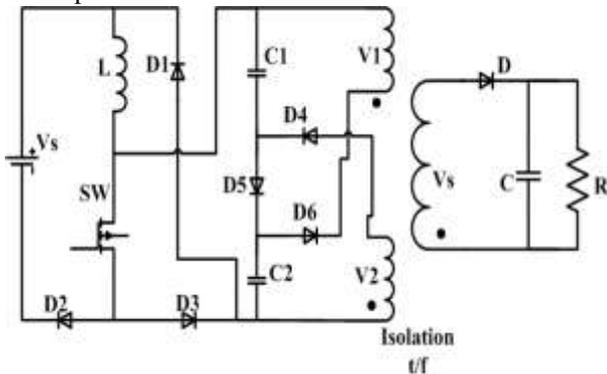

Fig. 1: Circuit Diagram of IBBSPFC

IBBSPFC circuit has four modes of operation. In 1st the power transfer capability in the way like by mode lever is closed and coil of inductor gets charged and the current flows from Supply voltage to inductor, inductor through switch that flows through diode D2 back to supply voltage. Mode 1 circuit diagram is shown in fig. 1(a).
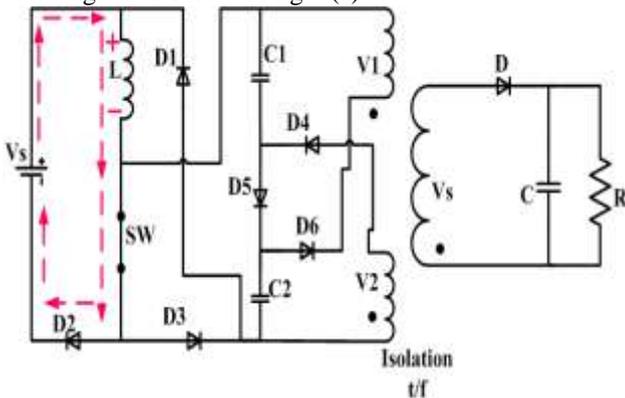
Fig. 1(a): Mode 1in the interval of $0 < T < t1$

In Mode 2 Switch is turned off inductor current gets discharged through capacitors so that the capacitors gets charged through C1 to D5, D5 to C2, C2 to D1 back to inductor so that it makes a closed loop. Mode 2 Circuit diagram is shown in fig. 1(b).

Mode 3 is shown in Fig. 1 (c), again lever is closed as mode 1 will repeat with capacitors gets discharged and the input side of the transformer will get energized [9].
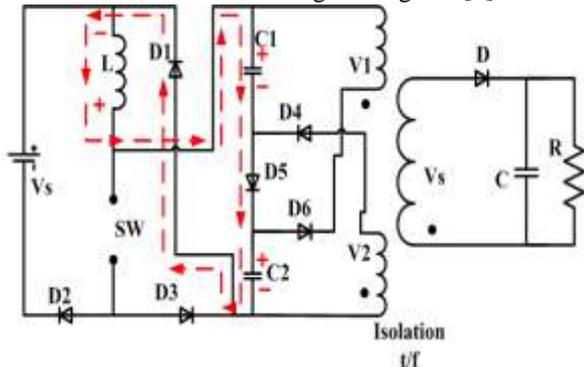
Fig. 1 (b): Mode 2 with limit $t_1 < T < t_2$
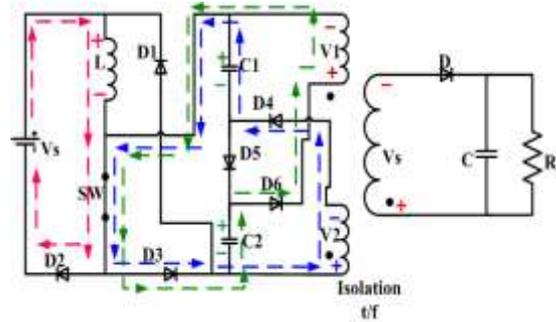
Fig. 1 (c): Mode 3 with limit $t_2 < T < t_3$

In 4th mode again mode2 gets repeated with the capcitors gets charged from the input side of the transformer gets de-energised from the capacitors so that capacitors gets charged. When the transformer gets de-energised at the input side then due to the dot convention the output side of the transformer gets energised so that output voltage is high or low compared to the input voltage as it is buck boost converter.

After mode 4 again mode 3 and mode 4 gets repeated. Mode 4 is shown in fig. 1(d).
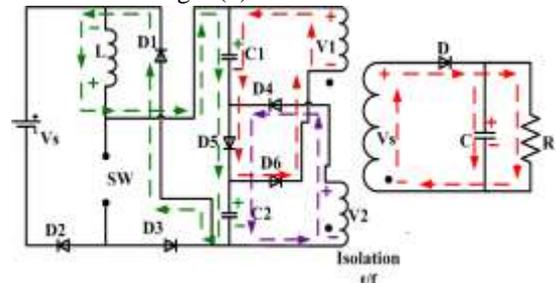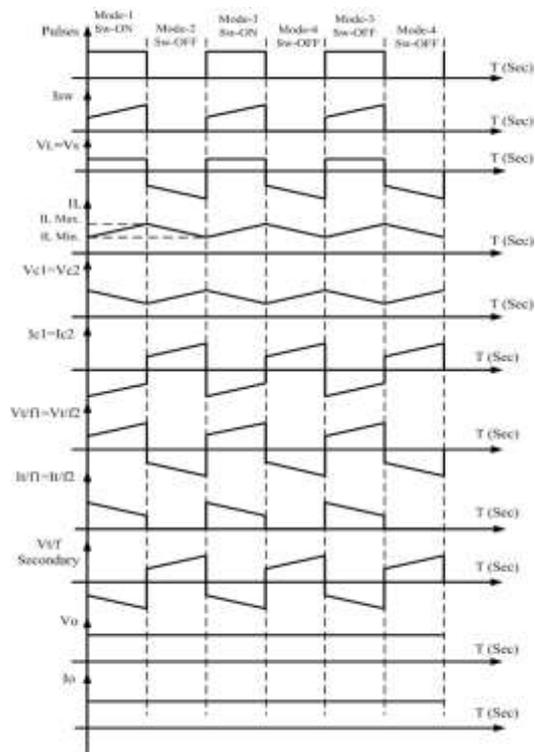

Fig. 1 (d): Mode 4 with $t_3 < T < t_4$

Fig. 2: Theoretical waveforms

For these four modes of operation *theoretical waveforms* are shown in Fig. 2.

III. MATHEMATICAL ANALYSIS

Mathematical analysis for IBBSPFC is presented below for:

$V_s = 24V;$

$V_0 = 50V;$

$I_0 = 2A;$

$f = 100KHz$

$P_0 = V_0 \, I_0 = 50 X 2 = 100W$ ----------- (1)

$P_0 = P_{IN}$

$V_0 I_0 = V_{IN} I_{IN}$

$100 = 24 X I_{IN}$

$I_{IN}(or)I_S = 4.166A$ ----------------- (2)

$V_L = V_S - V_{SW} - V_{D2}$

$V_L = 24 - 1.2 - 0.7$

$V_L = 22.1V$ ------------------------ (3)

$V_L = L\dfrac{di}{dt}$

$22.1 = L\dfrac{\Delta I}{DT}$

$22.1 = L\dfrac{0.05}{0.00001} \quad for \Delta i = 0.05A$

$L = 3.24mH$ -------------------------- (4)

$C = \dfrac{I_0 K}{f \Delta V} \quad$ Assume ΔV=1.35

$C = \dfrac{2 x 0.67}{10^5 X 1.35} = 10\mu F$ ------------ (5)

$i_c = c\dfrac{dv}{dt}$

$i_c = 10 X 10^{-6} X \dfrac{1.35}{0.00001}$

$i_c = 1.35A$ ------------------ (6)

$V_0 = \dfrac{V_S K}{1 - K}$

$50 = \dfrac{24K}{1 - K}$

$K = 0.675 = 67.5\%$ ----------- (7)

$V_0 = \dfrac{24 X 0.675}{1 - 0.675}$

$V_0 = 49.98$ ---------------- (8)

$V_{C1} = V_{C2} = \dfrac{1}{2}V_0$

$V_{C1} = V_{C2} = \dfrac{1}{2} \ X 49.94$

$V_{C1} = V_{C2} = 24.99V$ ------------- (9)

$P_T = (1 + \dfrac{1}{\eta})P_0$

$P_T = 100 X 2 = 200W$

$P_0 = 100W$

$I_{t1} = I_1 = \dfrac{200 - 100}{50}$

$I_{t1} = I_1 = 2A$ ------------- (10)

$\eta = \dfrac{P_0}{P_{IN}} = \dfrac{49 \times 1.83}{24 X 4.16}$

$\eta = 89.81\%$

IV. SIMULATION RESULTS

MATLAB model simulated results for the system shown in fig. 3. Whereas fig. 4 and figure 5 with a Switch V and I waveforms, Figure 6 and 7 with Inductor voltage and current waveforms, Fig. 8 shows Capacitor voltages Vc1 & Vc2, Fig. 9 shows capacitor currents Ic1 & Ic2 wave forms, Fig. 10 shows Transformer primary voltage Vpt/f1 & Vpt/f2, Fig. 11 have a primary current of the transformer Ipt/f1 & Ipt/f2, Fig. 12 & 13 Shows secondary voltage of the transformer and current & Fig. 14 & 15 shows Load voltage and load current.
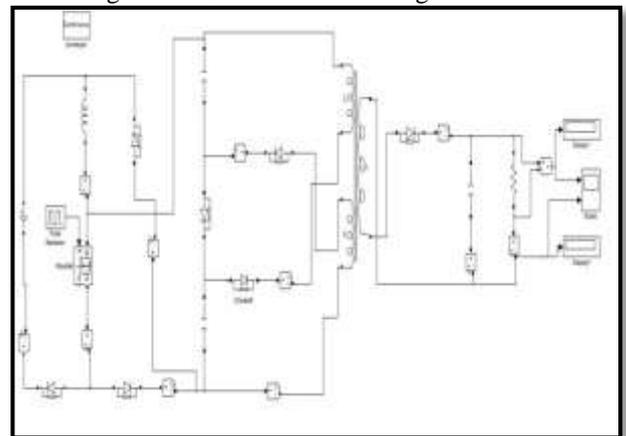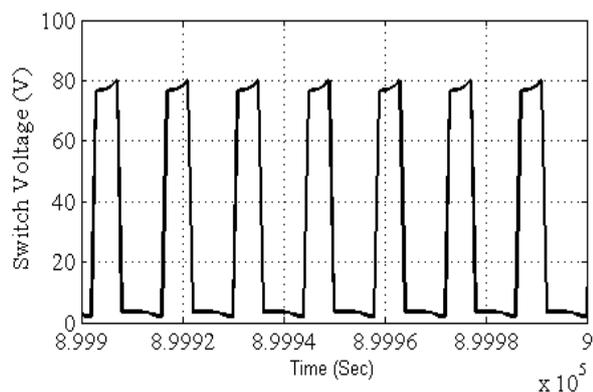

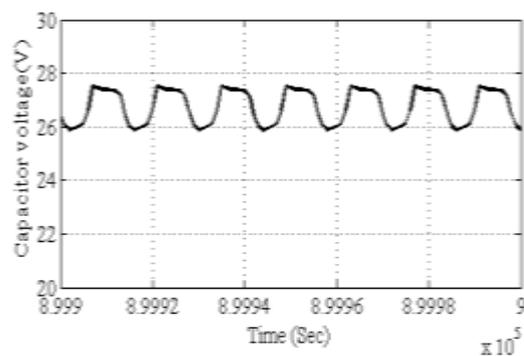**Fig. 3 MATLAB simulated Model**

Fig. 4: Switch Voltage

Fig. 5: Switch Current

Fig. 6: Inductor Voltage

Fig. 7: Inductor Current
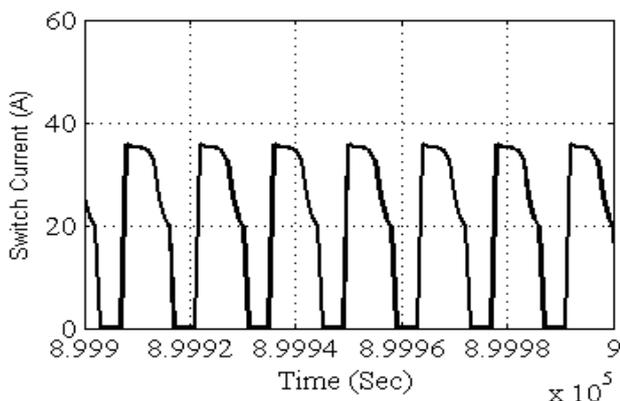
Fig. 8: Capacitor Voltages
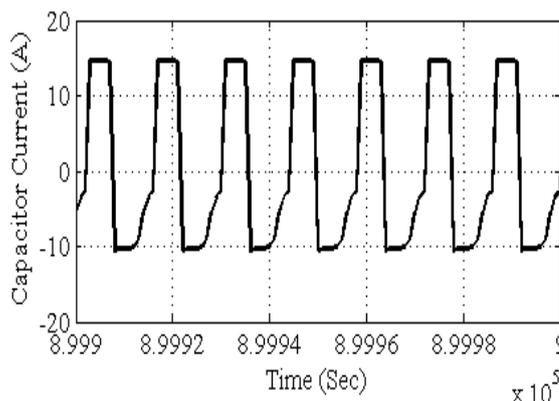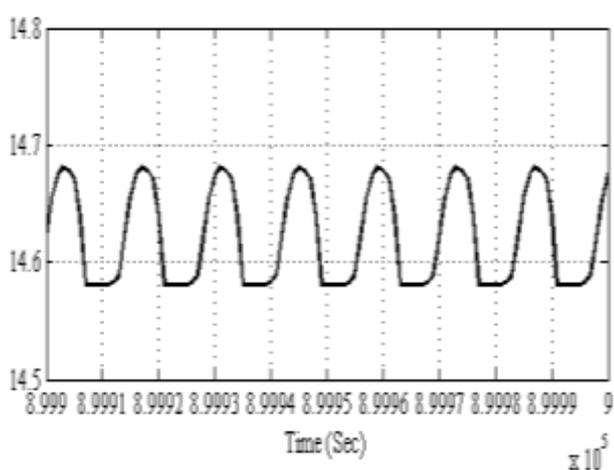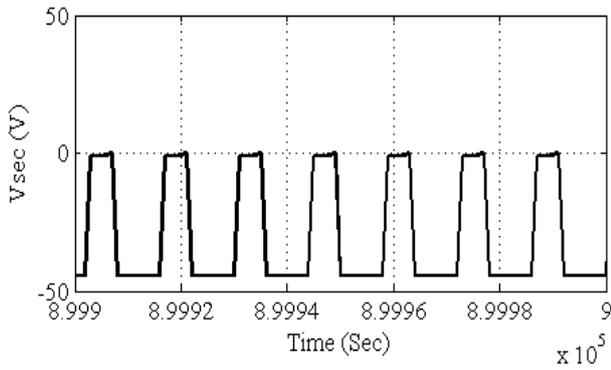

Fig. 9: Capacitor Currents
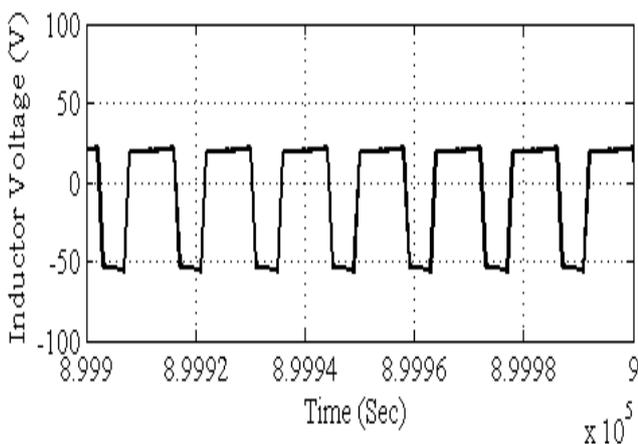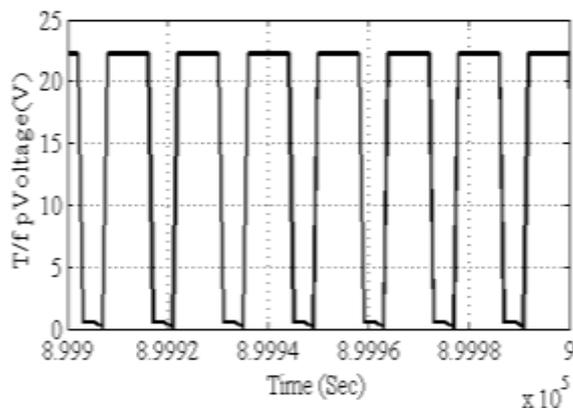
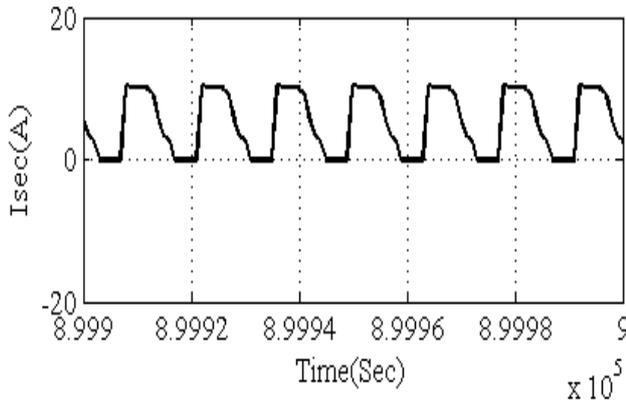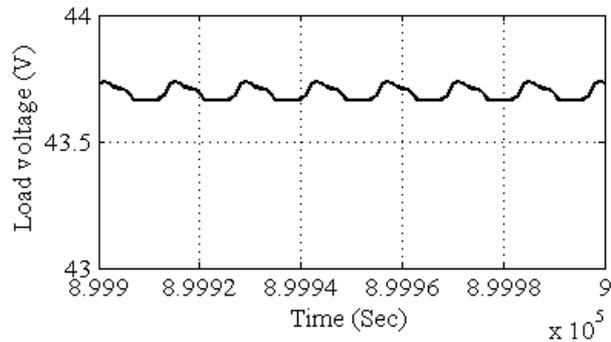**Fig. 10: 1st winding Voltage of Transformer**
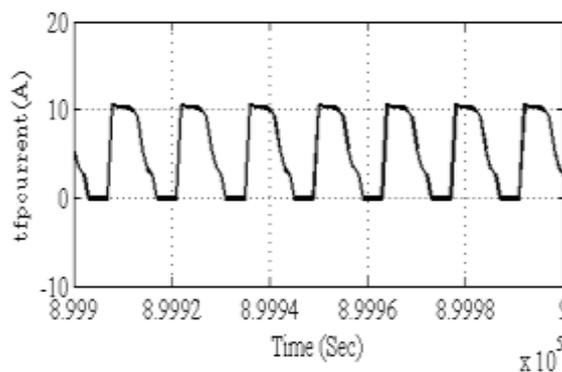
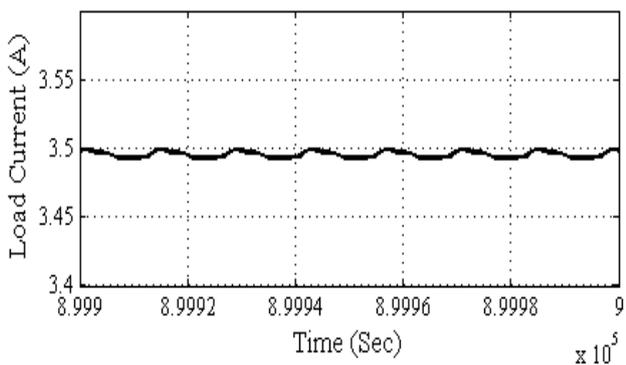**Fig. 11: 1st winding Current of Transformer**

Fig. 12: Transformer Secondary Voltage

Fig. 13: Transformer Secondary Current


Fig. 14: Output Voltage

Fig. 15: Output Current

V. EXPERIMENTAL RESULTS

The Home based kit with the Experimental results for Open Loop Control is shown with 24V input Voltage duty cycle is 67%. Fig.(16) Shows the hardware setup. Fig. (17 & 18) is Inductor voltage and current, fig. (19 &20) shows the

Capacitor Voltages & Currents, fig.(21 & 22) shows the transformer primary and secondary voltages, fig. (23) is transformer current, fig.(24) shows switch current and fig. (25) shows the output voltage and current waveforms.
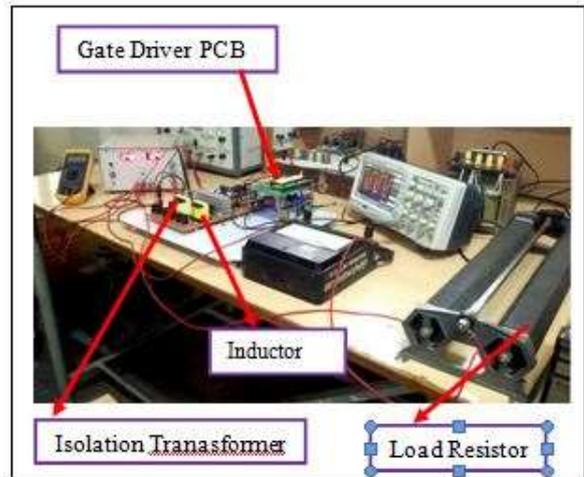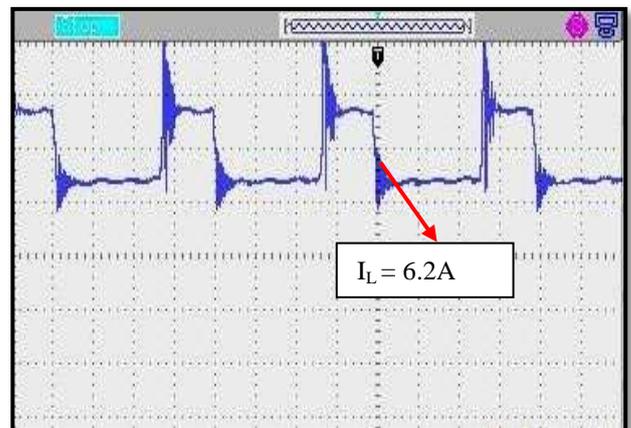

Fig. 16 – Hardware Setup of IBBSPFC

The Components used in the hard ware setup is Protection circuit, gate pulse circuit, reset circuit, inductor, capacitors, diodes, transformer, switch with heat sink.
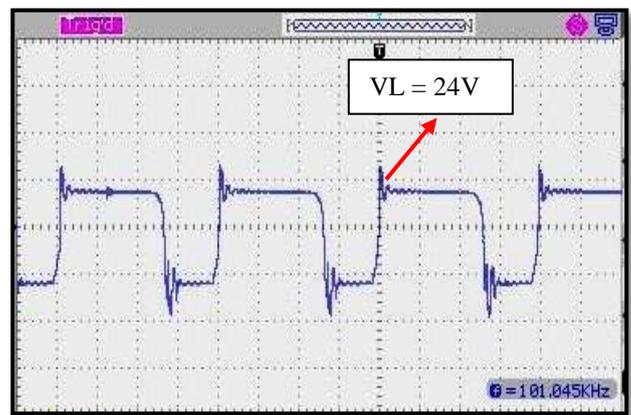
Fig. 17 - Inductor Voltage
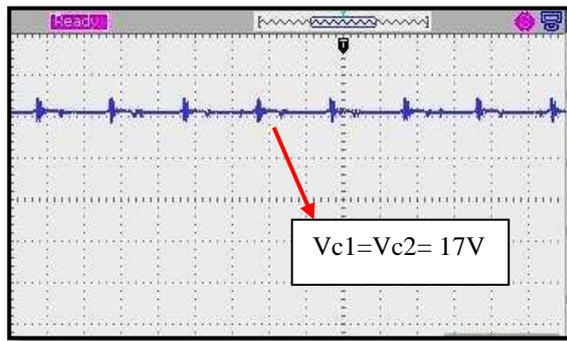

Fig. 18 – Inductor Current
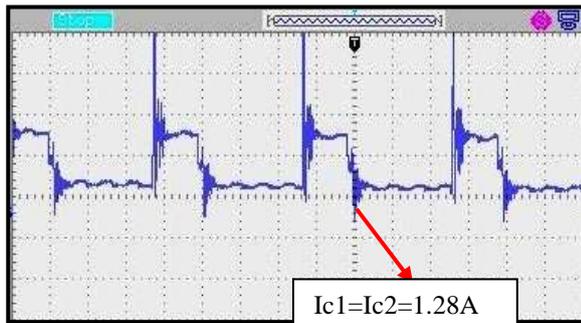
Fig.19 – Capacitor Voltages Vc_1 and Vc_2

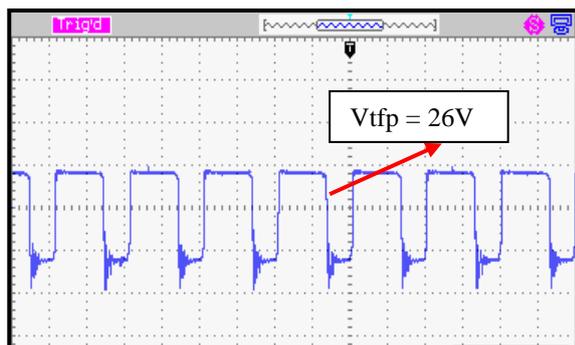Vc1=Vc2= 17V

Fig.20 – Capacitor Currents Ic_1 and Ic_2

Ic1=Ic2=1.28A

Vtfp = 26V

Fig.21 – Transformer primary voltages Vt_1 and Vt_2

Vtf = 52V
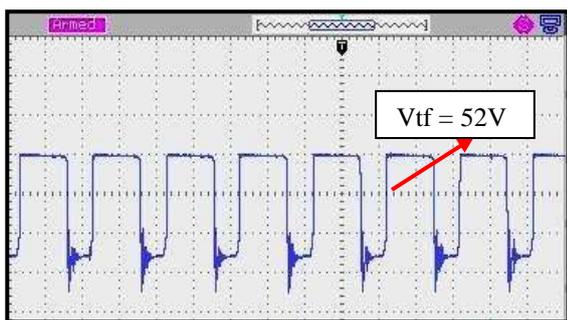
Fig.22 – Transformer Secondary voltage V_{Sec}

Itf= 2.6A
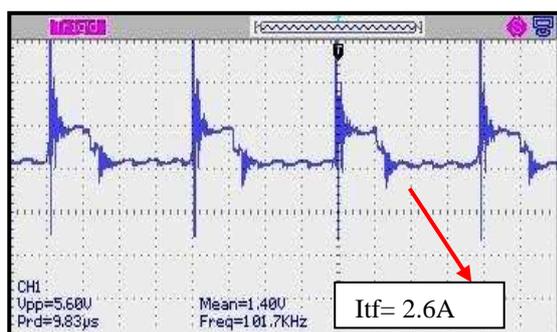
Fig.23 – Transformer Primary Currents

Isw = 1.6A

Fig.24 – Switch Current

Io = 1.5A

Vo = 46V
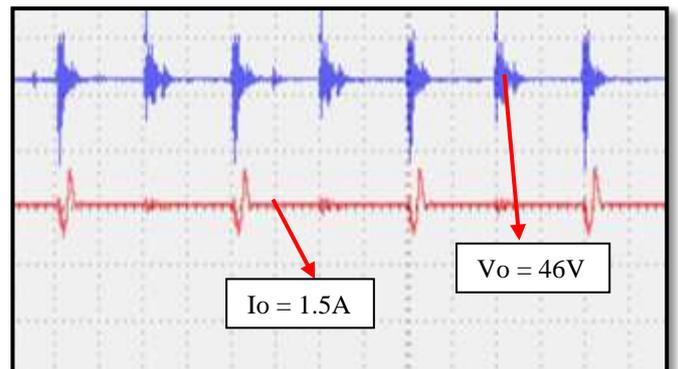
Fig.25 – Output Voltage and Current

VI. COMPARISON TABLE

Table 1 shows the comparison of simulation values and practical values with the voltage and current.

Parameter	Theoretical Value		Practical Value	
	Voltage [V]	Current [A]	Voltage [V]	Current [A]
Input Side	24	4.16	24	3.24
Output side	49	1.83	46	1.5
Inductor	24	6.3	22.58	6.249
Capacitor	20	0.56	17	0.78
Transformer 1 & 2	25	1.26	26	2.64

Table 1Comparison of theoretical and practical values

Table 2 shows the specifications of the hardware kit with the parameters used in the hardware prototype.

Parameter	Specification & Rating
Inductor	100KHz, 10µH, 8A
Capacitor	1000µF, 50V
Fast Recovery Diode	MUR3060 – 600V, 30A
Transformer	1:1, 25/25V
MOSFET	IRF460 – 500V, 21A

Table 2 Components specification

VII. CONCLUSION

The devise procedure with the circuit arrangement of IBBSPFC has been presented. The efficiency of the converter is nearly 90%, Advantage of this converter is only single switch is used so that switching stress is reduced, it has high transfer capability of power and reliability. The proposed circuit is simulated with supply input voltage of 24V and voltage output of 50V with 100 W power and switching frequency of 100 KHz.

This converter can be given to the renewable sources to get the voltage low or high to the inverter or to the loads. This paper can be extended further with solar PV cells with MPPT algorithm and the output of the converter can be taken to multi-loads from the secondary sides of the isolation transformer.

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