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Research Paper

DESIGN AND IMPLEMENTATION OF SINGLE STAGE INTEGRATED BUCK-FLYBACK CONVERTER BASED POWER SUPPLY

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This paper investigates the integrated buck- flyback converter as a good solution for implementing low- cost high-power-factor ac-dc converters with fast output regulation. It will be shown that, when both buck and flyback semistages are operated in discontinuous conduction mode, the voltage across the bulk capacitor, which is used to store energy at low frequency, is independent of the output power. This makes it possible to maintain the bulk capacitor voltage at a low value within the whole line voltage range. This project implements a buck converter for the first stage and flyback converter for output stage. These topologies are very good solution for fast output dynamics. Another advantage of this integrated buck-flyback converter, is that switch handles the highest of buck or flyback current not addition of both currents. The remaining current is handled by the diodes of the integrated switch, which gives lower losses. The buck capacitor voltage is independent of load, duty cycle, and switching frequency and it only depends on the ac input voltage and the ratio of the two buck and flyback inductance. This is an important feature of the integrated converter operating in discontinuous mode, which allows them to provide fast output voltage regulation. The simulation has been performed to verify the feasibility of the proposed LED lamp driver.

Keywords: Fast output regulation, Integrated buck-flyback converter, Single-stage ac-dc converter

INTRODUCTION

Recently Switched Mode Power supplies have become smaller and lighter due to higher switching frequency. There are four common configuration for switched mode power supplies flyback converter, forward converter, push-pull converter, Half-bridge Converter. In this flyback converter is widely used for high-output voltage at relatively low power. This project implements a buck converter for the

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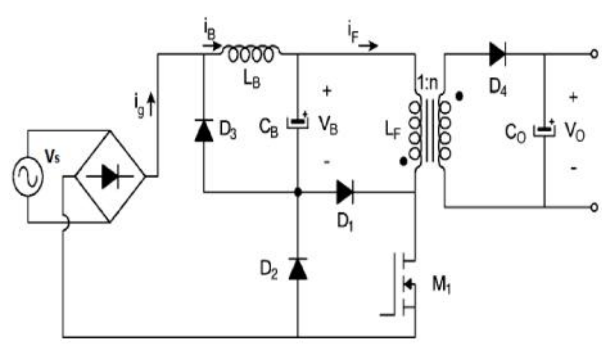
first stage and flyback converter for output stage. These topologies are very good solution, reaching unity power factor and providing fast output dynamics. In this project is the integrated buck-flyback converter. The converter operated in discontinuous mode. so, that high power factor can be achieved at the input, while the converter behaves as a current source at the output. Another advantage of this integrated buck-flyback converter, is that switch handles the highest of buck or flyback current and not addition of both currents. The changes on the duty cycle will affect only the output voltage, thus making it possible for a fast output voltage regulation.

PROPOSED FLYBACK CONVERTER

This topology is made by the integration of buck and flyback converters to obtain a fast output dynamics. It is composed of a buck converter working in DCM integrated with a DCM flyback converter. Its operation is equivalent to two converter in cascade.

Figure 1: Circuit Diagram of Proposed Flyback Converter



When the input ac supply is given to the full wave rectifier. It converts ac to dc output voltage. This dc output is given to the flyback converter. It produces the high frequency ac. This high frequency ac is step down to dc using half wave rectifier.

MODES OF OPERATION

The operating principle of the digitally controlled high power factor buck-flyback converter based power supply can be divided into four modes. For simple analysis of each mode of the proposed converter, the following assumptions are made.

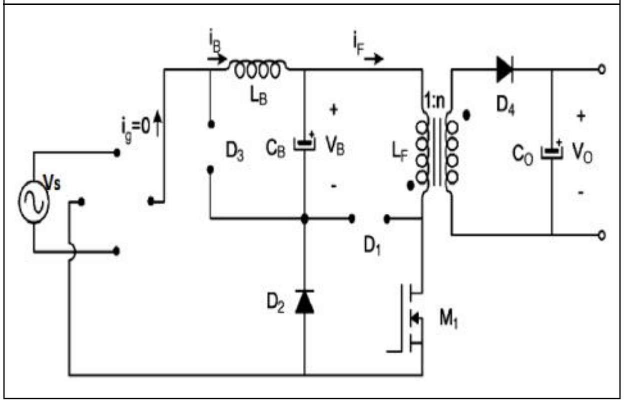
1. All switching devices and passive elements are ideal.
2. Bulk capacitor (CB) and output capacitor (Co) are fully charged.
3. The recovery time of all diodes is ignored.
4. The magnetic circuit is assumed to be linear and coupling between primary and secondary windings is assumed to be ideal.

For simple analysis of each mode of the proposed converter is explained below.

Mode 1: M1 is ON ($V_s < V_B$)

In the time intervals where the instantaneous line voltage is lower than the bulk capacitor voltage, the rectifier bridge diodes are reverse biased and remain open. Thus, the buck inductance is not energized and diodes

Figure 2: Mode 1: M1 is ON ($V_s < V_B$)



D_1 and D_3 are also open during these time intervals. Capacitor starts discharging through the load.

When the switch is ON the bulk capacitor starts discharging through flyback inductor,

$$\frac{1}{C_s}\int i_{CB}dt + L_F\frac{di_F}{dt} = 0$$

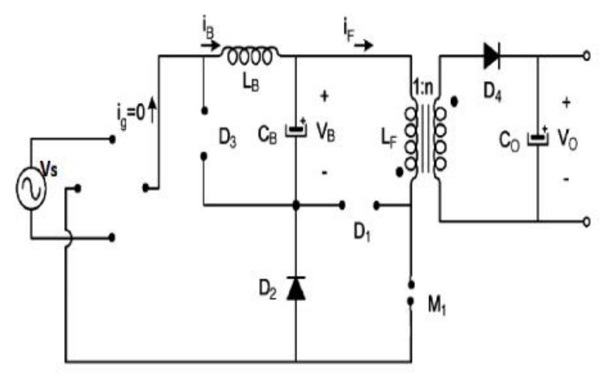
The output capacitor supplies the load,

$$\frac{1}{Co}\int i_{Co}dt - i_oR = 0$$

Mode 2: M1 is OFF

In this mode, bulk capacitor is fully discharged, the switch M_1 will be open. the secondary side of the diode D_4 will become forward biased. The C_0 charges as well as current flows through the load also. The voltage across the secondary side of the flyback inductor is equal to the sum of voltage across the output capacitor and the load.

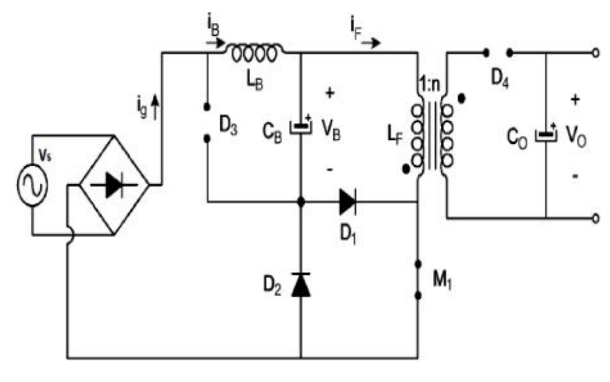
Figure 3: Mode 2: M1 is OFF



Mode 3: M1 is ON ($V_s > V_B$)

In this mode the instantaneous line voltage is higher than the bulk capacitor voltage. In this interval, both buck and flyback inductors are energized when the control switch M1 is activated. Diodes D3 and D4 will remain open

Figure 4: Mode 3: M1 is ON ($V_s > V_B$)

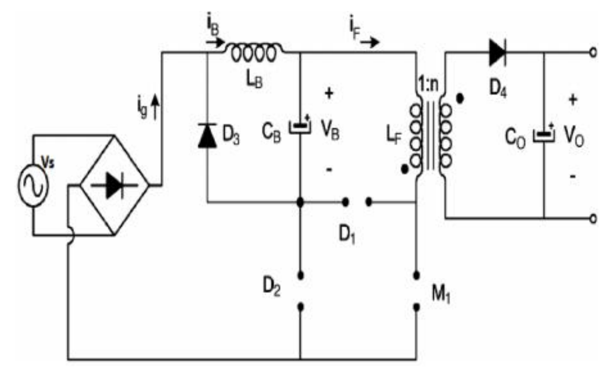


and the currents through the buck and flyback inductors are handled by the integrated switch formed by M_1, D_1, and D_2. In this circuit, the switch M_1 will handle the higher of the two currents i_B and i_F (buck and flyback currents, respectively). In this case, when $i_B > i_F$, current i_B will circulate through M_1, D_1 will handle the current $i_B – i_F$, with D_2 being off. Now the energy is transfer from L_B to C_B. when the switch is on, the supply voltage is equal to the sum of voltage across the buck inductor and voltage across the bulk capacitor. When $i_B < i_F$, current i_F will circulate through M_1, D_2 will handle the current $i_F – i_B$, with D_1 being off. Now the energy is transfer from C_B to flyback inductance. The output capacitor supplies the load.

Mode 4: M1 is OFF ($V_s > V_B$)

When the line voltage is higher than the bulk capacitor voltage, and the switch M_1 is open. During this interval, both buck and flyback inductors are being deenergized, and the energy is supplied to the bulk capacitor and load, respectively. In this stage, only diodes D_3 and D_4 will be conducting as long as energy remains in the magnetic field of the buck and flyback inductors, respectively. When the switch is opened, the voltage across the buck inductor and bulk capacitor

Figure 5: Mode 4: M1 is OFF ($V_s > V_B$)



are equal in magnitude but it has opposite polarity.

$$\frac{1}{C_B}\int i_{CB} dt + L_B \frac{di_B}{dt} = 0$$

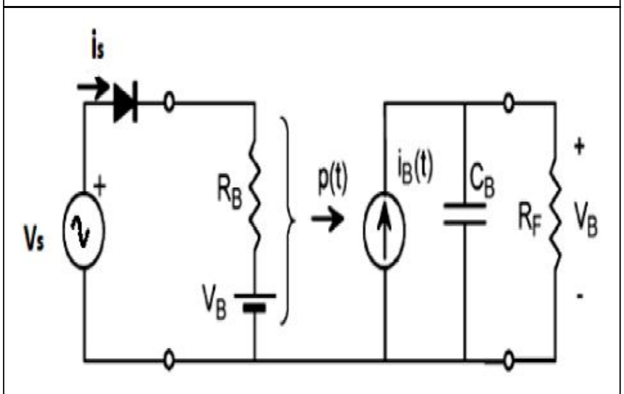
The voltage across the secondary side of the flyback inductor is equal to the sum of voltage across the output capacitor and the load.

$$L_F \frac{di_F}{dt} = \frac{1}{C_O}\int i_{CO} dt = i_O R$$

EQUIVALENT CIRCUIT

The instantaneous power consumed by the buck resistance and buck voltage source is transferred to the output section formed by the

Figure 6: Equivalent Circuit Diagram



filter capacitor and equivalent resistance of the flyback converter resistance. The power can be calculated, therefore assuming negligible ripple voltage across capacitor.

The instantaneous Power can be calculated,

$$p(t) = v_S\left(\frac{v_S - V_B}{R_B}\right)$$

Assuming negligible ripple voltage across the capacitor C_B,

$$i_B(t) = \frac{V_{sm}}{R_B}\left(\frac{V_{sm}\sin^2\omega t}{V_B} - \sin\omega t\right)$$

The output power can be calculated as follows,

$$P_0 = \frac{(V_B)^2}{R_B}$$

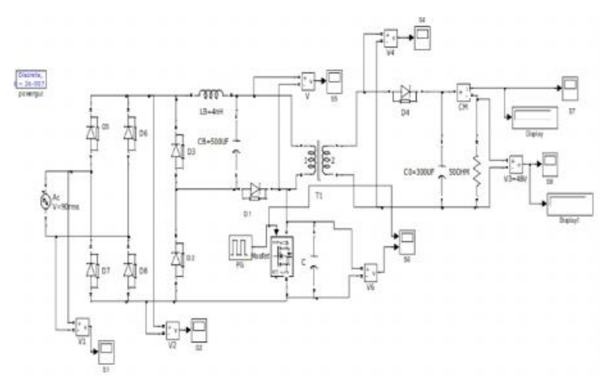
$$R_F = \frac{2L_F F_S}{D^2}$$

$$R_B = \frac{2L_B F_S}{D^2}$$

SIMULATION DIAGRAM OF INTEGRATED BUCK-FLYBACK CONVERTER

The simulation diagram of proposed converter is been drawn using MATLAB software and the results have been analysed. The Figure 7 shows the simulation diagram of the proposed flyback converter. The ac supply voltage V_s is fed to the full bridge rectifier which consists of diodes D_5, D_6, D_7, D_8. The MOSFET is used as a switch S_1. The switch S_1 is triggered from pulse generator

Figure 7: Simulated Diagram of IBFC

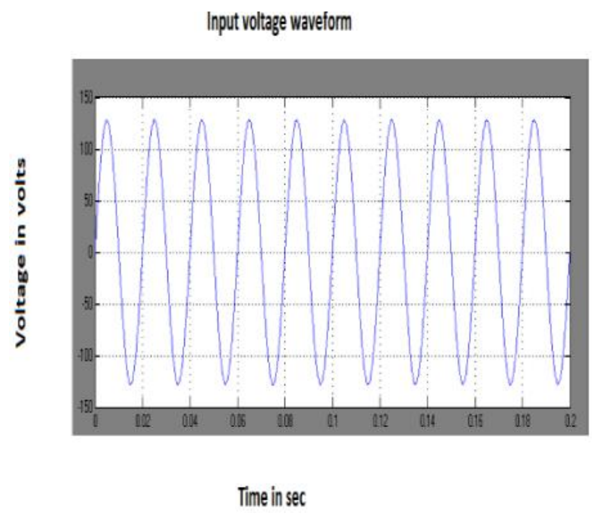


whose switching frequency is 100 Khz. The input given is 90 V ac sinusoidal voltage. D_4 acts as a half bridge rectifier. The *Co* acts as the output filter capacitor which removes all the ripples present in the output voltage The output obtained is 48 V dc voltage.

INPUT VOLTAGE

The Figure 8 shows the input voltage waveform with time in X-axis and voltage in Y-axis. The input voltage given is 90 v rms. The waveform is measured by connecting scope to the voltage measurement block.

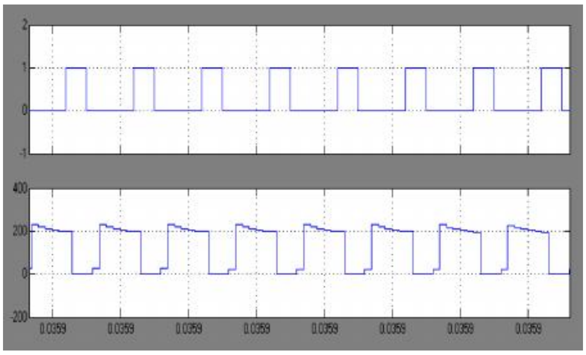
Figure 8: Shows the Input Voltage with Time in X Axis and Voltage in Y Axis



GATE PULSE OF THE SWITCH

The gate pulse of the switch S (MOSFET) is given with a duty ratio of 0.5, i.e., 50% of the total period. The adapted value of duty ratio is selected to be 0.5 for an enhanced output voltage. The gate pulse given to the switch is shown below in the diagram.

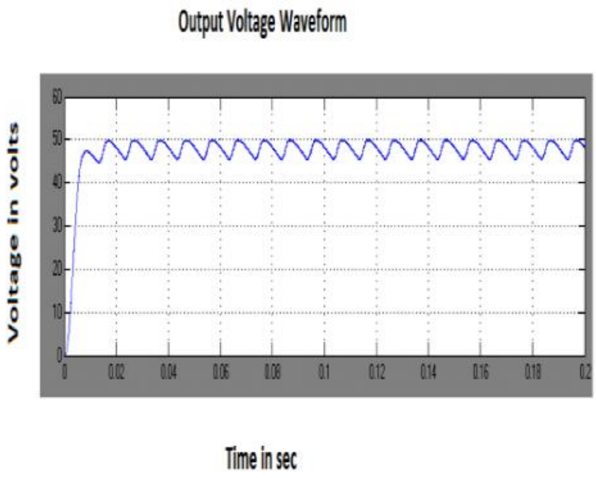
Figure 9: Gate Pulse of the Switch



OUTPUT VOLTAGE

The Figure 10 shows the output voltage waveform with time in X-axis and voltage in Y-axis. The value of the output current obtained is 48 V.

Figure 10: Shows the Output Voltage with Time in X Axis and Voltage in Y Axis



CONCLUSION

This project researches a Integrated buck-flyback converter. The IBFC is proposed as a good solution to implement low-cost HPF ac–dc converters with fast output regulation. The operation of both semi stages in DCM provides a bulk capacitor voltage independent of the duty cycle and output power. Thus, the bulk capacitor voltage can be maintained at a low value within the whole line voltage range. Thus, the bulk capacitor voltage can be maintained at a low value within the whole line voltage range. The different operating modes have also been illustrated, showing that the control switch handles lower rms current than other SS integrated topologies.

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