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Research paper

An Improved Power Factor Correction for Interleaved Flyback Switched Mode Power Supply

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Abstract

Nowadays the use of electronic equipment finds a progressive development in the modern world. Hence it becomes a mandate to check whether the harmonic content of line current of any electronic device which is connected to the ac supply meets the appropriate standards. This demand is satisfied by implementing the Power Factor Correction (PFC) circuit in order to make the input current to be in sinusoidal in nature and in-phase with the input voltage. Numerous solutions are available to make the line current almost sinusoidal. This paper deals with the inclusion of passive PFC in the interleaved Fly back SMPS to improve the power factor. The proposed work also examines the reduction of current ripple at the output using interleaved converter.

Keywords: *Power factor correction (PFC), current ripple, interleaved fly back SMPS.*

1. Introduction

Switched Mode Power Supplies have been accepted to be one of the effective methods of delivering power to electronic devices. SMPS devices are lighter in weight and size, cost effective and produce greater efficiency. Out of various topologies available in SMPS, Fly back converter has become familiar since it is simple in design, cheap and have better efficiency [1]. Generally, fly back converters are chosen where the loads need to be isolated from ac supply for low power applications. Both step up and step down action of the input voltage is done using Fly back converter while sustaining the similar polarity and ground reference for input as well as output. For high switching frequency and low power applications, MOSFET is used as the switching device. Compared to all other switching devices, the turn on and off time of MOSFET switch is very less which in turn reduces the switching losses. The filter component size gets reduced due to the high switching action of MOSFET [2]. The fly back converter can be used for both DC-DC as well as AC-DC converter with electrical separation between the inputs and the outputs. For better accuracy, the fly back converter is similar to a buck-boost converter having the inductor split acts like a transformer whose voltage ratio is multiplied with the added benefit of isolation. During the ON state, the energy from the input source is transferred to the transformer meanwhile the load gets energy from the output capacitor. During the OFF state, the energy from the transformer is transferred to both output capacitor as well as the load. By controlling the duty cycle of the switch used in the primary side of the transformer, a variable DC output of zero to a maximum value is obtained [3].
Switched Mode Power Supply plays a vital role in the computer where the conversion of ac to several number of appropriate dc voltages takes place in order to transfer power to various parts of the Personal Computer. Switched Mode Power Supply comprises of a bridge rectifier, filter capacitor and a DC-DC Converter which produces multiple DC output voltages. The charging and discharging of the input capacitor produces a greatly distorted and high value of crest factor at the single phase ac supply [4]. The line current drawn by the power semi converter devices is highly distorted which gives a low power factor and very high Total Harmonic Distortion (THD). As a result, Power factor improvement and line current harmonic reduction becomes a mandatory one [5]. The major drawback of the Diode rectifier from the AC mains is that it produces high pulsating current and a very poor power factor. In order to enhance the power quality, a passive filter is the best choice as its circuit is very simple in structure. Enormous control strategies and circuit topologies of power factor correctors are readily available to reduce the voltage or current harmonics and making the power factor to almost unity. Various Power Factor Correction (PFC) methods are available to rectify the above power quality issues. In the beginning, this paper involves the simulation of the fly back based SMPS and the voltage and current waveforms are analyzed. In this paper a T filter is used to increase the power which is used in different dc/dc and ac/dc applications. Initially the circuit is simple in construction and it becomes advanced by introducing passive PFC method and interleaved topology. Moreover by focusing mainly on the voltage and current waveform, the purpose of enhancing the current waveform i.e. making it to near sinusoidal is achieved [6]. Also with the use of interleaved topology, the circuit becomes quite complex and the current ripple is greatly reduced.

2. Background

Switched Mode Power Supply is a major part in the computer, which converts ac to several dc voltages, to power various parts of the PC. The SMPS circuit consists of a diode bridge rectifier, an input capacitor and the DC-DC converter produces multiple DC output voltages. The capacitor's uncontrolled charging and discharging yields a distorted and high crest factor at the ac side which exceeds the limit of power quality standards. In order to overcome the above problem, enhanced power quality SMPS with unity power factor are generally under research. Recently various topologies for power factor correction application have been developed [7]. Nowadays in AC-DC power conversions, Power factor corrected converters are greatly used in order to attain low harmonic distortion and enhanced power factor. Personal computer (PC) is the mainly affected by power quality problems among other electronic equipment. To power up various parts of the PC, Switched-Mode Power Supplies (SMPS) are greatly used. At the front side of the SMPS, a diode bridge rectifier is used. It is this diode bridge rectifier which caused a considerable drop in power quality, owing to high harmonic distortion and low power factor at the ac side. Due to the above issue, the current waveform becomes non sinusoidal and highly distorted. By employing Power quality improvement techniques, enhanced power quality, greater efficiency and reliability will be achieved [8]-[9]. To convert power from the single-phase ac grid for dc loads, Switched-mode rectifiers are used which should meet severe requirements like high power factor, low EMI noise, higher efficiency and reliability [10]. The major goal in power electronics is the higher efficiency and high value of Power Factor (PF) which can be attained by the switched-mode rectifiers to transfer real power from the ac grids to the dc loads[11]–[12].

3. Need for Enhanced Power Factor

Generally, a highly distorted current is obtained from the mains during conventional AC rectification. Due to this, a greater spectrum of harmonic signals will be generated at the ac side which then interfaced with other equipment. Through power factor correction, there are number of advantages achieved. They are

- Decreased demand charges
- Increased load carrying capabilities
- Enhanced voltage
- Decrease power system losses

To enhance the power factor and reduce the THD value of input current, power factor correction methods are used. Out of various power factor correction methods, passive PFC is dealt with. Generally, passive power factor correction involves the inclusion of a line frequency inductor in the AC line. The inductor's work is to flatten the current wave shape that resists the change in current. The smoother current wave-shape indicates less harmonic distortion in the ac side. This passive PFC is the simplest solution out of other methods. It is impractical in power supplies above 300 W owing to the component size required to offer sufficient inductance at 50 Hz and to keep the resistive losses minimum.

4. Existing System

The fly back based SMPS converts an AC input voltage into a regulated DC. Based on its transformer turn's ratio, the higher or lower output voltage will be obtained. The conventional fly back SMPS comprises of a bridge rectifier ,an input capacitor, a high frequency switching device, a fly back transformer, an output rectifier and an output capacitor to produce a regulated DC output. A simplified fly back based SMPS circuit diagram is shown in Fig 1.

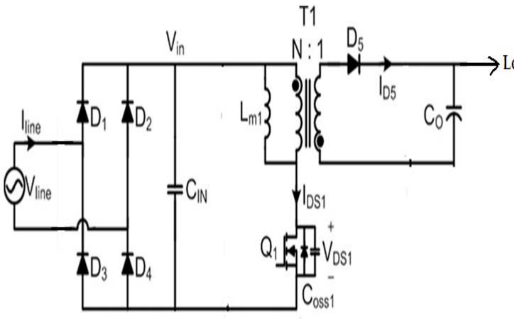

Fig. 1: Conventional fly back based SMPS circuit diagram

In Fly back converter, isolation between the primary and the secondary side is achieved by imparting power transformer.

Mode 1 (Switch Q_1 is closed): During the turn ON of the switch 'Q_1', the input supply is connected with the transformer's primary winding with its dotted end linked to the positive side. Meanwhile, the diode 'D_5' which is in series with the secondary winding becomes reverse biased in the secondary because of the induced voltage. So when the switch Q_1 is in ON position, the primary winding carries the current while the current through the secondary is restricted because of the reverse biased diode. The flux establishment in the transformer core is mainly because of the primary current.

Mode 2 (Switch Q_1 is open): During the turn ON of the switch 'Q_1', the primary current as well as the magnetic flux reduces. The voltage at the secondary is positive, making the diode to forward bias, and which allows the current to flow from the transformer to the load. The energy from the transformer core charges the capacitor as well as supplies the load.

Design Parameter and Equations for Fly Back Converter

$V_o = D\,(N_2/N_1)\,V_{in}/\,(1 - D)$

$L_m = D*V_{in}/(\Delta I_{Li})\,f_s$

$C_o = V_o*D/(fs*R*\Delta V_{co})$

Where

f_s = switching frequency

ΔI_{Li} = peak to peak ripple current

ΔV_{co}= voltage ripple

N_2/N_1= Transformer turn ratio

5. Proposed System

Fig 2 shows the proposed interleaved fly back SMPS circuit diagram. The single phase AC supply is given to the PFC unit which improves the power factor. The output from PFC unit is fed to the rectifier. Rectifier converts it to DC. The rectifier output is then fed to the interleaved fly back converter. The converter is controlled by pulse width modulation. The regulated DC output is obtained.

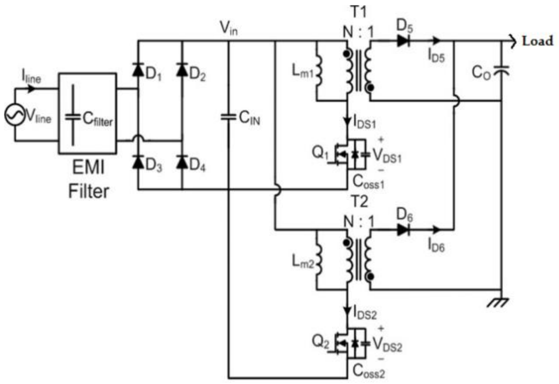

Fig. 2: Proposed interleaved fly back based SMPS circuit diagram

Operating Principle

The operation of interleaved SMPS is classified into six modes. The first three modes are similar to the next three modes. The first three modes are elucidated from that that the remaining modes can be understood. Some assumptions are made in order to make the circuit operation simple. They are as follows

- Transformer leakage inductances are inconsiderable.
- The magnetizing inductances Lm1 and Lm2 are similar.
- There is an exact 180^o phase shift between the two switches.

Mode 1: During mode 1, the switches Q_1 and Q_2 are turned ON and OFF respectively. The magnetizing inductor Lm1 starts energizing while the inductor Lm2 transfers the stored energy to the output via the diode D_6. The diode current ID_6 starts to decrease.
Mode 2: As the diode current ID_6 starts decreasing and it reaches zero, mode 2 starts. Still the switch Q_1 is in ON condition. The output capacitor Co starts to discharge and supplies the load.
Mode 3: Mode 3 begins as the switch Q_1 turns OFF. The inductor Lm1 transfers the stored energy to the output via the diode D_5. The diode current ID_5 starts to decrease. Mode 3 ends as the diode current ID_5 becomes zero.
The remaining three modes of operation are similar to the first three modes.

Advantages of interleaved topology

- Reduction of size of the filter components.
- Cheap
- Decreased EMI energy because of low peak currents.
- C_o is larger than C_{in} which makes the output voltage to have lesser ripple content.

6. Simulation Results

Fig 3 shows the simulation diagram of cascaded fly back SMPS without PFC. The input voltage waveform and current waveform are shown in Fig 4 which shows a greater phase shift between the voltage and currents indicating a low power factor. The output voltage and output current are given in Fig 5 and Fig 6 indicating a low ripple in the voltage and current by using interleaved converter as compared to the conventional fly back SMPS.

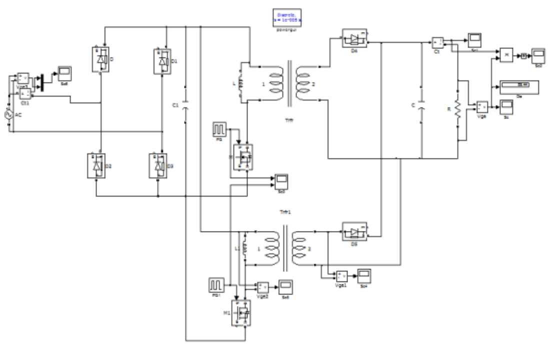

Fig. 3: Simulation diagram of cascaded Fly back converter without PFC

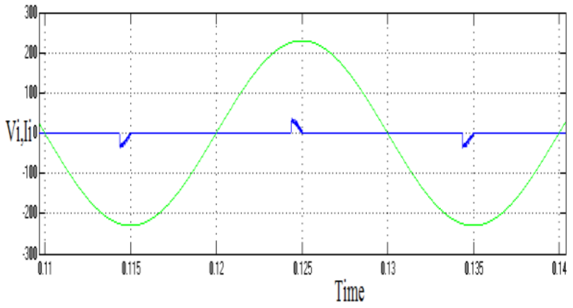

Fig. 4: Input voltage and current

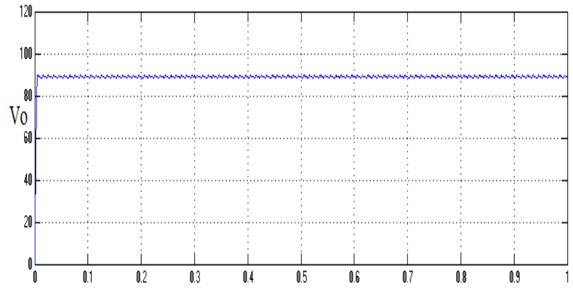

Fig. 5: Output voltage

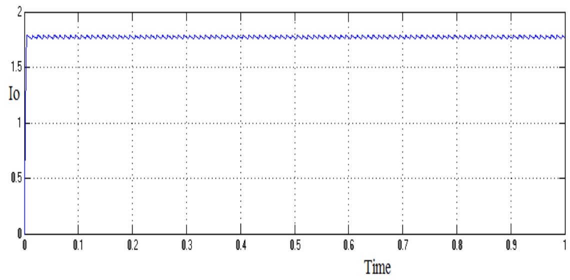

Fig. 6: Output current

Fig 7 shows the simulation diagram of cascaded Fly back SMPS with T filter which gives an improvement in the power factor. The input voltage waveform and current waveform are shown in Fig 8 which indicates the zero phase-shift between the voltage and the current. This current waveform reaches near sinusoidal and the power factor has been improved. The output voltage and output current are given in Fig 9 and Fig 10.[13][14]

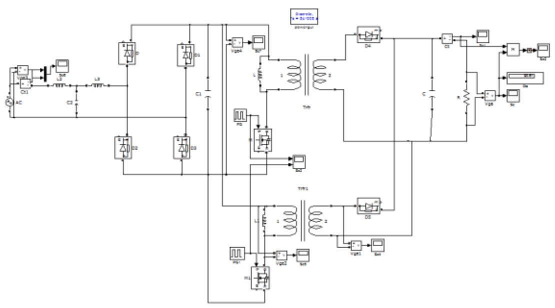

Fig. 7: Simulation diagram of cascaded fly back converter with T filter

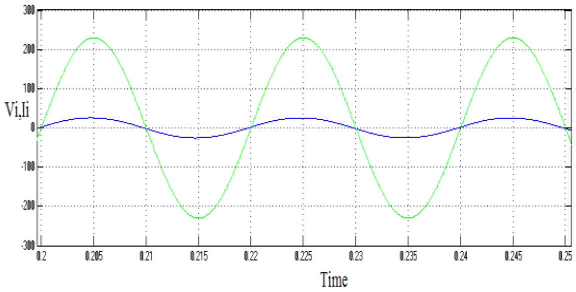

Fig. 8: Input voltage and current

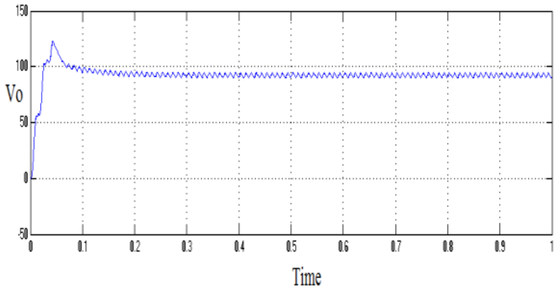

Fig. 9: Output voltage

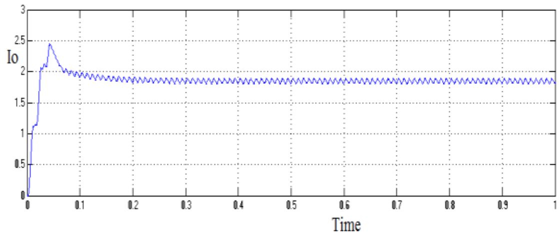

Fig. 10: Output current

7. Conclusion

The proposed converter presents nearly a regulated DC output with lesser ripple content. By using this proposed converter, the component count can be reduced. Also the filtering components used are less in size. Thus the interleaved fly back based SMPS is an appropriate choice for wide power range applications. From the simulation results, it is noted that without PFC, there is a greater phase shift between the current and voltage indicating a poor power factor. By using passive PFC, the phase shift between voltage and current becomes nullified and the current waveform approaches near sinusoidal waveform. This implies that power factor has been greatly improved by using the PFC techniques. Compared with the conventional PFC, the proposed PFC has the benefit of lower devices rating, cheap and low EMI noise.

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