A New Advanced Topology for Photo Voltaic Applications

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ABSTRACT
This article proposes a high efficient DC-DC step-up converter with a single switch. This is particularly suited for Photo Voltaic (PV) applications, automotive applications, battery operated vehicles etc., in which voltage is stepped up from 10V to 500V. This converter operates at 100 kHz due to which switching losses are comparatively high. This topology proposes a scheme to mitigate power losses across the switch and to achieve high efficiency by Zero Current Switching (ZCS) at “Turn ON and Turn OFF” states. Proposed converter uses a single switch to reduce the losses in the converter and 98% overall efficiency has been observed in the converter. The proposed converter is verified by its experimental results.

1. INTRODUCTION
The field of DC-DC converters has witnessed many rigorous investigations leading to successful operation in Photo Voltaic (PV) systems. The ever increasing demand of industry for stability, adjustability and accuracy of control of power electronic equipment at very high voltages led to the development of relatively less total harmonic distortion (THD) based modern power electronic static converters. Although solid state power electronic switches, such as the IGBTs have brought well-marked variance in control techniques, nonetheless the main disadvantage is that they produce heavy loss in the converter switches. Many converters are operating with dual switches which produce more loss on systems which are operated with PV cells. Hence, it though of opportunity to reduce the switches in DC-DC converters with less losses. Thus there is always scope of reducing losses in DC to DC converters. Also it has developed a control mechanism to control the switches in synchronism with the switches. It also uses a single voltage sensor there by the cost of equipment also reduces. The use of a single voltage sensor and the application of an OPAMP as comparator can reduce the cost of the circuit.

High step-up DC-DC converters have multiple usages in day to day life, such as applications powered by battery sources, PV cells, and high intensity discharge (HID) lamp ballasts etc., This calls for qualitative performance improvement of their operations. As an example, most commonly used headlamps in automotive applications are HID lamps, where the start-up voltage is up to 200 V-500V, the DC–DC converter needs to boost the 12 V/24V of the battery source voltage available in vehicle up to 200 V-500V during its steady-state operation. Normally this achieved with the help of inverter-rectifier cascaded connection, which is a most uneconomical approach. Conventional boost converters are able to achieve high step-up voltage gain as required for applications in heavy duty operating conditions.

In practice, however, the voltage gain of the DC-DC converters are limited owing to the losses associated with the main power switches. The switch-off and switch-on losses due to the main power switch will degrade the efficiency of the converter. In order to increase the conversion efficiency and voltage gain, a
number of modified boost converter topologies have been proposed [1–5] in literature. Hence, in order to overcome the above mentioned drawback, this work proposes a high efficient topology with soft switching scheme. In [1], it proposes an isolated DC converter and its experimental verification is shown in [2]. For micro source applications [3-5] such as fuel cells, applications isolated DC converters has been proposed. The detailed analysis and its experimental verification have been shown in [4]. A new robust control mechanism was proposed in [6-8] and new topologies for DC-DC converters was proposed [9-11] to reduce losses in the system. Also, a type of Zero Voltage (ZVS) and Zero Current Switching (ZCS) was proposed to reduce [12-16] the losses. Hence by keeping all above improvements and drawbacks in consideration, it proposes a new DC-DC converter with single switch with a single voltage sensor which will be discussed in following sections.

This paper is organized in five sections. Section -1 introduces the relevant literature survey about DC – DC converters. In section -2, modeling of proposed converter has been put forward. In section-3, this article discuss about the simulation and experimental results of proposed controller; and in the last section, the conclusive remarks have been been provided.

2. PROPOSED TOPOLOGY AND ITS OPERATION

In this section the proposed topology and its modes of operation has been presented. Primarily, the switching scheme has been proposed and shown in fig.1. In which the output voltage of the converter has been sensed and compared with required reference and the resultant signal has been passed through the voltage of converter compare with the required reference and obtained signal has been passed through the modulator as shown in figure 1.

![Figure 1: Gate driver for circuit for proposed DC-DC converter](image)

The basic proposed converter topology is shown in fig. 2 and its gate driver circuit is shown in figure 1. The proposed DC-DC converter basically consists of a battery source with its voltage as \( V_{in} \) and its input current as \( I_{in} \); converter is comprised of diodes \( D_1, D_2 \) and \( D_3 \); inductors \( L_1, L_2 \) and \( L_3 \) with its respective voltages and currents as \( V_{L1}, V_{L2}, V_{L3} \) and \( I_{L1}, I_{L2}, I_{L3} \); capacitors \( C_1, C_2 \) and \( C_3 \) with its respective voltages and currents as \( V_{C1}, V_{C2}, V_{C3} \) and \( I_{C1}, I_{C2}, I_{C3} \); load voltage and load current as \( V_L \) and \( I_L \) respectively; \( T \) is the total time taken for a duty cycle, \( V_{ramp} \) is the voltage given to modulator in ramp wave, \( V_{ref} \) is the reference voltage that needs to obtain at the output terminals of converter, \( f \) is the operating frequency of the switch \( S_1 \) the voltage across the switch is denoted as \( V_{S1} \). Where \( L_1 \) and \( L_3 \) are coupled inductors. The input voltage for modulator is taken as \( +V_{cc} \) and \( -V_{cc} \).
Mode 1 ($0 < t_0 < t_1$): Initially it is assumed that the capacitor $C_2$ and $C_3$ was fully charged. When the switch $S_1$ is turned ON, the diode $D_1$ will become forward biased as shown in figure 2 (a). Since the inductor is placed in series with the switch it does not allow sudden change in current and hence zero current switching takes at the time of switch ON. The currents will follow the path $+V_{in}-D_1-L_1-S_1- -V_{in}$. On the other hand, the capacitor $C_1$ is delivering the energy to coupled inductor $L_1$. At this instant the inductor $L_1$ is trying to discharge the energy to $L_3$ due to its coupling effect. Next, the capacitor’s $C_2$ and $C_3$ are continuing to deliver its energy to the load and it is maintaining the required voltage at the terminals as shown in fig. 3(a). The voltage is calculated after several algebraic express as shown in (1).

$$V_0 = D.V_{c1} + (D + 1)V_{c2}$$  \hspace{1cm} (1)

Where 'D' is the duty cycle of the switch $^\text{D} = \frac{T_{on}(\text{Switch ON time})}{T(\text{Total time})}$. 

\hspace{1cm}
Mode 2 \((t_0 < t_1 < t_2)\): At this instant the switch \(S_1\) still is in ON condition. The coupled inductor \(L_1\) transfers the energy to \(L_2\) and then \(L_3\) starts delivering the energy to capacitor \(C_3\) to charge. Still the capacitor \(C_2\) still continuous to deliver the energy to load as show in fig. 3(b).

Mode 3 \((t_1 < t_2 < t_3)\): At this instant still the switch \(S_1\) is turned in to OFF condition by removing the gate pulse. Due to presence of \(L_2\) the switch \(S_1\) ensures the zero current switching. Once the switch \(S_1\) is OFF, \(D_1\) becomes forward bias. The current will follows the path of \(+V_{in} - L_2 - C_1 - V_{in}\). Here the input current will splits the current in two ways such as one is to energise the capacitor \(C_1\) and other is to couple inductor \(L_2\) as show in figure 3(c). The input current splits into two ways so that one will energize the capacitor \(C_1\) and the other is to the coupled inductor \(L_2\).

Mode 4 \((t_2 < t_4 < T)\): At this instant still the switch \(S_1\) is still in OFF condition. At this instant, the current will follows the path of \(+V_{in} - L_2 - C_1 - V_{in}\). The capacitor \(C_1\) is trying to charge up to its capacity and coupled inductor will dissipates energy in its internal magnetic circuit as shown in figure 3(d).
3. EXPERIMENTAL VERIFICATION

In this section the proposed topology has been verified by its experiments and results have been discussed.

![Diagram of proposed converter showing mode-3 operation](image)

**Figure. 3(d) proposed converter showing mode-3 operation**

All modes of operation in terms of their output wave forms is shown in figure (4).

![Output waveforms for the proposed converter in continuous conduction mode](image)

**Figure. 4 Output waveforms for the proposed converter in continuous conduction mode**

Figure 4 shows the switching operation of DC-DC converter. The obtained switching pulses from modulator have been given to the switch and its current and voltage waveforms as per modes of operation have been given. The proposed topology has been verified experimentally and shown in fig.(5).It shows currents through the coupled inductors $L_1$ and $L_2$ and inductor which is in series with the switch $L_2$.The ZCS condition has been verified at turn ON and OFF times of switch. The current passing through the inductors along with its switching voltages is shown in fig. (5). this experiment has been verified at 24 V and at 12 V input voltages by different loadings. By experimental analysis, the ZCS achieved at ON and condition and ZVS is obtained at OFF condition by which the losses of system has been reduced drastically. At 12V, the highest efficiency achieved is up to 98.1% at 50% of full load; in case of full load condition, the efficiency is...
achieved up to 94.3%. When the 24V input voltage, the efficiency is achieved up to 95.5% at full load condition, while at 50% of full load, the maximum efficiency is 98.3%.

![Diagram](image_url)

Figure. 5 Experimental Output waveforms for the proposed converter in continuous conduction mode

4. **CONCLUSION**

The article has been proposed a high efficient DC-DC converter with the principle of zero current switching schemes operated with single switch. The modes of operation with its experimental results have been reported and efficiency of system has achieved 98.3% at 24V DC input at 50% of its load condition.

5. **PARAMETERS CONSIDERED**

$V_{in} 12/24V, L_1, L_2, L_3, C_1, C_2, C_3$ are 26μH, 12μH, 26μH, 880μf, 220μf, 220μf respectively. $f_s=100kHz$; Output power $P_o=500W$; $D_1, D_2, D_1, D_3$ are STUS5B8; $S_1$ is IXAN0065.

**REFERENCES**


BIIOGRAPHIES OF AUTHORS

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