

Design, Analysis and Implementation of Tapped Inductor Boost Converter for Photovoltaic Applications

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Abstract:

DC - DC converters are widely used in a variety of applications. It is mostly used in tracking maximum power point of PV array. The tapped inductor is a feasible method to extend the voltage conversion ratio. In this paper, the effect of tapped inductor in a boost converter is discussed. This paper provides a detailed design and analysis of a tapped inductor boost converter. The performance of the proposed converter is compared with the conventional boost converter. Simulation of the proposed converter is performed in MATLAB/SIMULINK and the results are verified. A prototype of the proposed boost converter is built and the results are verified.

1. Introduction:

The idea behind this paper is put to use, on ground, the principles of generating electricity from the solar panels. The common problem faced with solar panels and generation techniques is that the supply produced as a result of photo electricity is a dc supply. This dc supply, is disadvantageous in the sense, it can't be transported without losses as the voltage is not high enough to overcome these factors. Therefore, the novelty of the paper lies in using a tapped inductor which increases the voltage gain and efficiency of the boost converter[1-2]. This topology provides wide voltage conversion range as well which can be integrated to a switched mode power converter to enhance the power conversion

efficiency. In a conventional boost converter, the voltage gain is limited by duty ratio. But the tapped inductor boost converter offers high boosting capability without high duty cycle, reduced stress and increased efficiency[3-5].

The basic operation and design of tapped inductor boost converter is discussed in this paper. Without increasing the complexity of the circuit, the proposed converter results in high boosting gain by controlling the tapped turns ratio of winding. A detailed comparison of the conventional boost and tapped inductor configuration is presented which includes the parameter such as voltage gain and ripple. Simulation results verify the analysis and confirm the performance of the proposed converter. The results indicate that the proposed tapped inductor improves the voltage gain at low value of duty cycle without any additional circuitry. The simulation results are verified experimentally.

2. Basic Operation of Tapped Inductor Boost Converter:

The working of the tapped inductor boost converter (TIBC) is similar to that of the conventional boost converter (CBC). When the MOSFET is in the ON state the inductor on the input side starts charging and the inductor on the output side also charges due to mutual inductance of the inductors. Due to the tapped inductor, the current shape

through the inductor windings is different compared to the boost converter with uncoupled inductor[6-7]. When the MOSFET is in the OFF state, both the inductor discharges and the output at the load increases and is found to be significantly more than that if the conventional boost converter (CBC).

Where V_{in} - Input voltage, ΔI - Inductor current ripple and D - Duty cycle

The output capacitor is as follows:

$$C = \frac{DI_o}{f_s \Delta V_o} \tag{3}$$

The conversion gain is given by

$$V_o = \frac{DN_2 + N_1}{(1-D)N_1} V_{in} \tag{4}$$

where ΔV_o - Capacitor voltage ripple and f_s - switching frequency.

3. Simulation Results

Based on the design equations, the tapped inductor boost converter is designed and the values are shown in table:1.

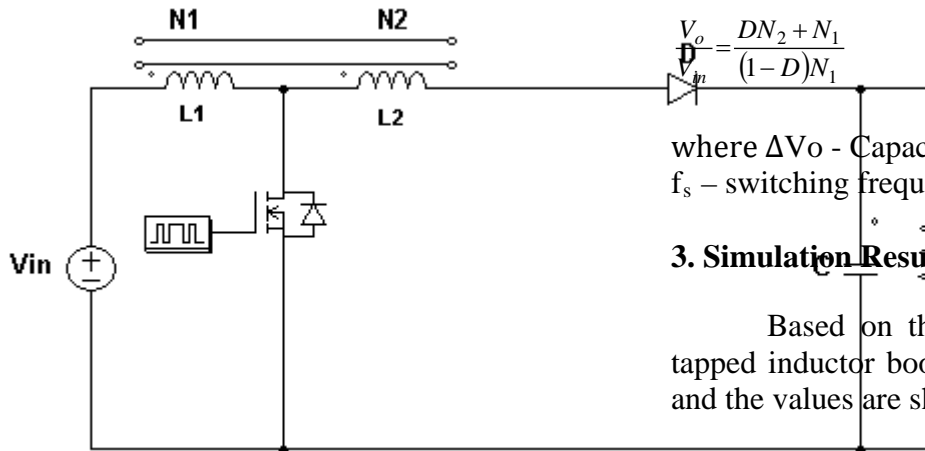


Fig.1. Circuit diagram of Tapped Boost Converter

In the proposed converter, the windings N_1 and N_2 are on the same core as they are magnetically coupled. The relation between L_1 and L_2 is determined by the turns ratio and is given by

$$\frac{L_2}{L_1} = \left(\frac{N_2}{N_1} \right)^2 \tag{1}$$

High gain can be achieved in the tapped inductor boost converter if a high value of coupling coefficient is chosen for a low value of duty ratio.

The value of the inductor is given by

$$L_1 = \frac{V_{in} DT}{\Delta I - I_o \frac{N_2}{N_1 + N_2}} \tag{2}$$

Table: 1 Simulation Parameters

Parameter	Value
Input Voltage (V_{in})	12V
Inductor (L_1)	500 μ H
Inductor (L_2)	1500 μ H
Capacitor (C)	220 μ F
Switching Frequency (f_s)	25 kHz
Duty ratio (D)	50 %
Resistance (R)	100 Ω

The proposed circuit is simulated in MATLAB/SIMULINK and the output voltage is shown in Fig.2.

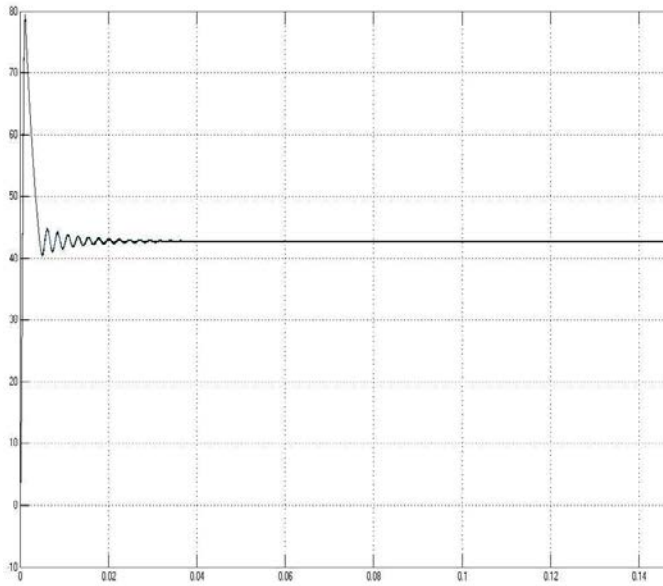


Fig.2. Steady State Output Voltage of TIBC

Fig.3 shows the output voltage and it is seen that the transients exist only for 30 ms and it reaches steady state voltage.

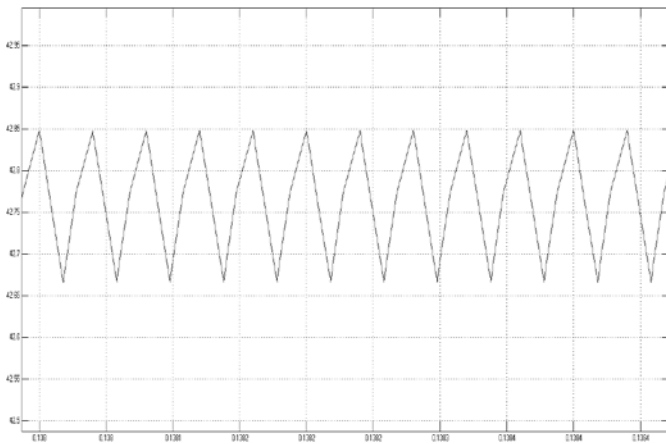


Fig.3. Output Voltage Ripple of TIBC

The output voltage ripple of 0.183 V is obtained as shown in Fig.4.

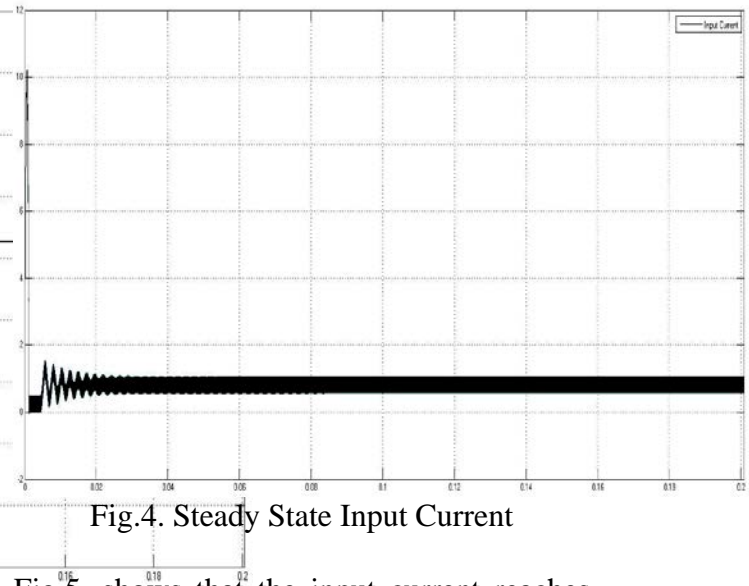


Fig.4. Steady State Input Current

Fig.5. shows that the input current reaches steady state at 40 ms and the transients are almost eliminated.

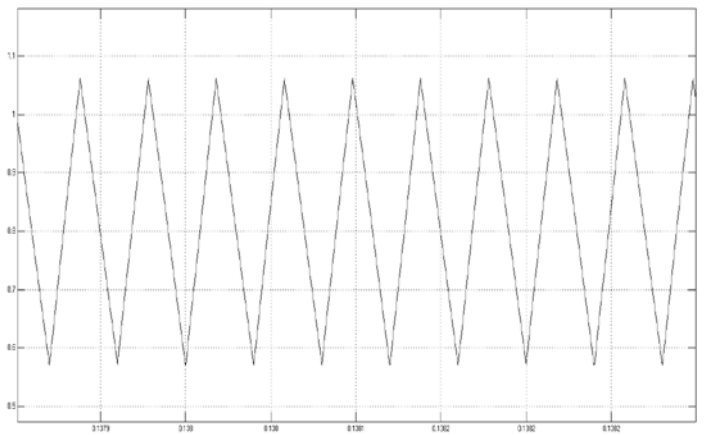


Fig.5. Input Current Ripple of TIBC

A ripple of 0.4 A is observed in the input which is less compared to the conventional boost converter.

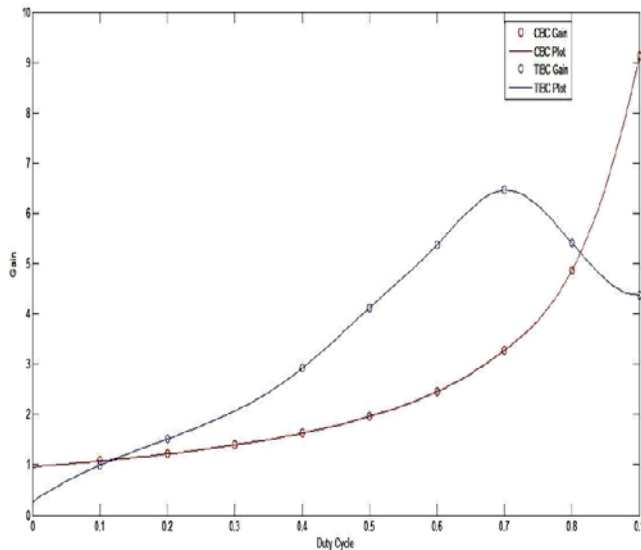


Fig.6. Duty Cycle Vs Gain of TIBC and Conventional Boost Converter

Fig.6 compares the gain of the conventional boost converter (CBC) and tapped inductor boost converter (TIBC). From the graph we infer that the gain of the tapped inductor boost converter (TIBC) is significantly greater than that of the conventional boost converter (CBC).

3. Experimental Results

The prototype of the tapped inductor boost converter is shown in Fig.8. The hardware setup consists of main power circuit, pulse generation circuit, power supply unit for pulse circuit and optocoupler circuit. The pulse generation circuit is shown in Fig.7. For duty ratio of 0.5, an output voltage of 90V is obtained where the conversion gain is four times higher than the conventional boost converter. Therefore, TIBC is best suited for PV applications where high gain is achieved without increasing the number of components in the circuit.



Fig.7. Pulse generation circuit for TIBC

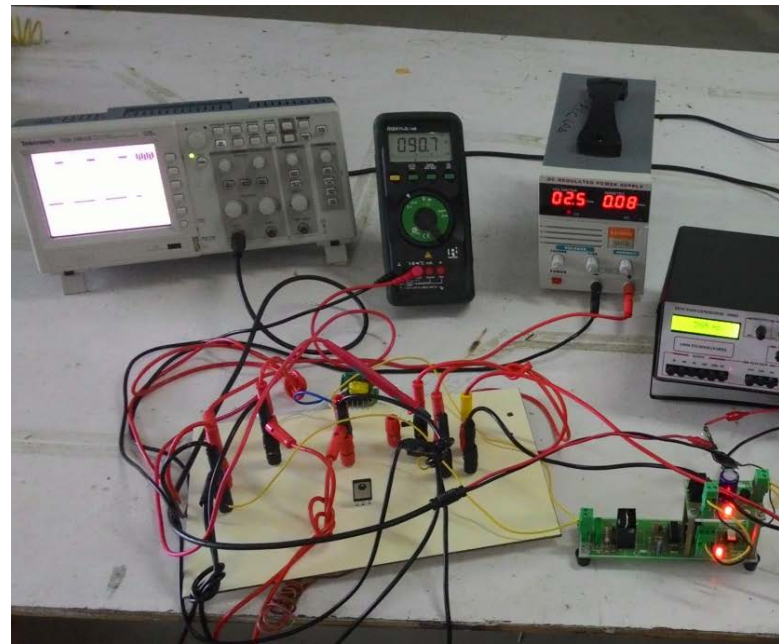


Fig. 8. Prototype of the Tapped Inductor Boost Converter

Conclusion:

This paper has investigated the performance of tapped inductor boost converter under steady-state. It is inferred from the results that the TIBC provides a

high boost factor compared to the conventional boost converter. The output voltage ripple and voltage stress across the device is also reduced. The simulation results are verified experimentally. Hence, TIBC is a suitable option for photovoltaic applications.

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