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MULTIPLE OUTPUT SINGLE INDUCTOR BOOST CONVERTER WITH HIGH STEP-UP GAIN

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Abstract: DC-DC boost converters with better performances, including improved voltage gain, efficiency and reliability, are urgently needed for wide range applications. In this project, a multiple output single-inductor boost converter (MSLBC) with ultrahigh voltage boosting capability with multiple output ports is designed and analysed. For the MSLBC, low-voltage-rating MOSFET with small on-resistance can be chosen and losses of switch can be reduced owing to the lower switch voltage stress and intrinsic small duty cycle, which are used to enhance the system efficiency. The single inductor of the MSLBC is in series with the input source, therefore, continuous input current is attainable. This converter can be used for the renewable energy applications especially battery charging. Moreover, the positive output and high gain of the converter is also beneficial for the renewable energy harvesting. The designed converter is analysed using the MATLAB/SIMULINK 2017.The converter has an efficiency of 90 % and lower voltage ripple. The switching pulses for the control circuit is generated using PIC16F877A micro– controller. The experimental results obtained from the converter prototype confirm the theoretical considerations and simulation results.

***Index Terms* - Boost Converter, Multiple Output, Gain, Efficiency**

I. Introduction

The name boost converter is not new, from early period onwards different studies are going on for improving better efficiency, reliability and gain and also reducing the voltage ripple. A single inductor boost converter [1] is an ultra-high gain boost converter which has a ultra-high gain which uses a single inductor technique to produce ultra-high gain can be used for renewable energy application. As an important part of the future intelligent power distribution system, dc microgrid [2] can efficiently and reliably integrate distributed renewable energy generation system, energy storage unit, electric vehicle, and other electric loads. Dc–dc converters, which are the key link to realize energy transfer between the units of dc microgrid, are widely researched and applied recently with the proper turn ratio of transformers, isolated converters can realize electrical isolation and high voltage gain. Applying the energy regenerative snubber and bipolar voltage multiplier structure, an isolated boost converter which possesses soft switching and flexible gain extension is presented in. In, a three-switch [3] isolated boost converter with continuous input current, reduced one active switch, added passive components, and no snubber circuit is analyzed. However, for the non-isolated applications, the adopted transformer will increase the system volume, cost, and weight. Coupled inductor [4] converters are one of the typical dc–dc converter topology types. Combining with interleaved strategy, two kinds of transformer less boost converters with lower ripples are presented in and. The former converter has better dynamic response and reduced efficiency while the latter converter possesses small duty cycle range and zero current switching. With two hybrid voltage multiplier cells, a three-winding coupled inductor converter is presented in. A boost converter is analyzed in by merging different switched-capacitor techniques and coupled inductor. In, deriving by the association of coupled inductor, boost cells, voltage multiplier, switched capacitors and LC filter cells, a series of hybrid boost converters are studied and analyzed. The abovementioned converters in all are single switch structures, but, more passive components are needed to construct these topologies.is used and there is absence of inrush current. Coupled inductor converters [5] are one of the typical dc–dc converter topology types. Combining with interleaved strategy, two kinds of transformerless boost converters with lower ripples are presented in. The former converter has better dynamic response and reduced efficiency while the latter converter possesses small duty cycle range and zero current switching. With two hybrid voltage multiplier cells, a three-winding coupled inductor converter is presented in. A zeta buck-boost converter [6] for single-input muultiple output applications. the proposed cnverter has three-output type with Dc bipolar voltage. It uses a single switch which reduces the switching loss and the gate controlling becomes easy. The proposed converter has low corrent stress on the output capacitor.This converter provides inverted and non-inverting outputs. A non-isolated buck-boost dc-dc converter [7] with single switch. This proposed converter has dual output topology. This converter has a wide range of conversion ratio. It has high step-up voltage gain without extreme duty ratio.The use of single switch has reduced the switchng losses and the gate control is simple.It has common ground but inverted output. A boost converter is analyzed in by merging different switched-capacitor techniques and coupled inductor. In, deriving by the association of coupled inductor, boost cells, voltage multiplier, switched capacitors and LC filter cells, a series of hybrid boost converters are studied and analyzed. The above-mentioned converters in all are single switch structures, but, more passive components are needed to construct these topologies.

In order to address the aforementioned issues a multiple output single inductor boost converter is proposed. This converter has three output and the voltage ripple is comparatively less keeping the gain constant. This boost function can utilize maximum amount of energy with optimum usage of input source and used in wide range of applications. The switches are synchronously controlled so the control circuit is also simple**.**

II. METHODOLOGY

The multiple output single inductor boost converter has three output terminals and one of which is used for the charging purpose. The single inductor technology enhances the output voltage of the converter. The converter consist of one inductor L_1 six capacitors C_1, C_2, C_3, C_4, C_5 and C_0, six diodes D_1, D_2, D_3, D_4, D_5, and D_0 and two switches $S_1$and S_2.The Fig.1 shows the circuit diagram of the proposed converter.

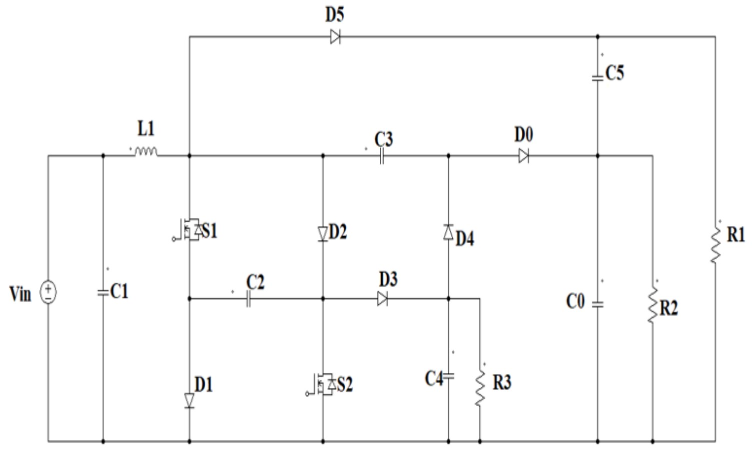


Fig. 1 Multiple Output Single Inductor Boost Converter

2.1 Modes of Operation

For this converter there are two modes of operation are there that is it is continuous mode operation and the theoretical waveform is shown in Fig.2.

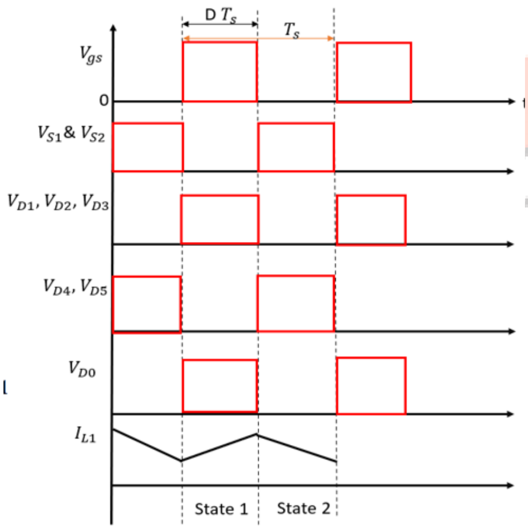
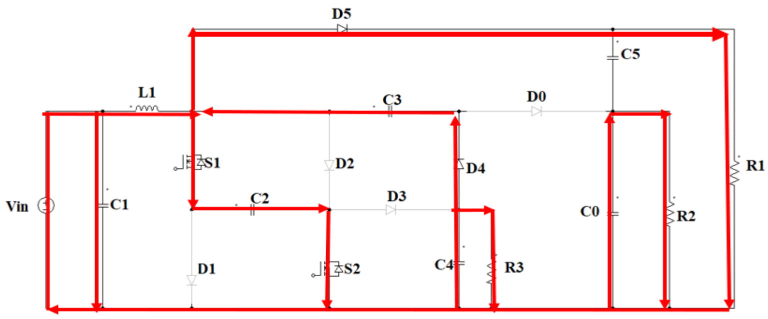
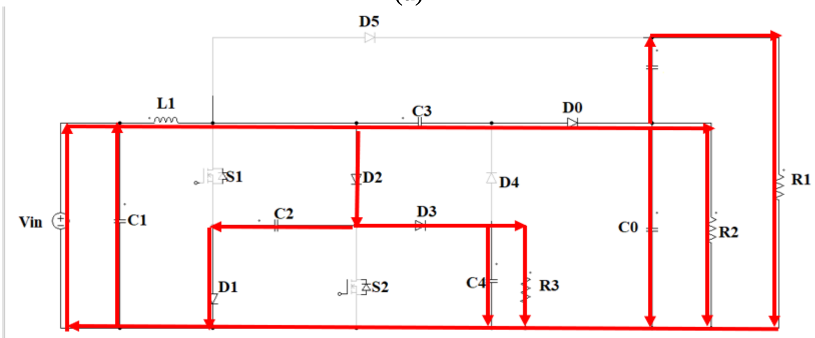


Fig. 2 Theoretical Waveform of Boost Converter

At state 1, the two synchronously controlled switch S_1 and S_2 are turned on together with the diode $D_4$and D_5 the other diodes become reverse biased simultaneously. Then the inductor L_1 becomes energised and capacitorsC_2 and C_5 charges. The capacitors C_1, C_3, C_0, and C_4 discharges and the output is given by the resistor R_1, R_2 and R_3 Fig.3(a) shows the mode 1 operation. In state 2 with in this period the switches S_1 and S_2 are turned on the mid-diodes D_1, D_2, D_3 and D_0 forward biased simultaneously. Then the inductor L_1 charges the capacitor C_2 discharges. The capacitors C_1, C_3, C_0 and C_4 charges. The mode 2 operation is shown in Fig.3(b).



(a)



(b)

Fig. 3 Operating Modes. (a) Mode I; (b) Mode II

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2.2 Design of Components

In order to work the converter according to the specification's components need to be designed. Some assumptions are taken for the design of multiple output single inductor boost converter. it consists of design of load resistance, inductor L_1 and capacitors C_2, C_3, C_4, C_5 and C_0.The input voltage is taken as 30V. The output power and voltage are taken as 250W and 300V. The switching frequency is 30kHz. Set $r_{i1}\%I_{L1}$ = 25%,$r_{C2}\%V_{C2}$= 10%, $r_{c3}\%V_{C3}$= 10%,$r_{c0}\%V_{CO}$= 1% and $r_{c5}\%V_{C5}$= 1%.

Duty Ratio can be found by (1) which is taken as 0.4. The value of load resistor is set as 35Ω in (2).

$$\frac{V_O}{V_{in}} = \left(\frac{3}{1-2D}\right) \tag{1}$$

$$R = \frac{{V_O}^2}{P_O} \tag{2}$$

The inductors L_1 is obtained by taking current ripple as $r_{i1}\%I_{L1}$ = 25%. By substituting values to (3) 1mH..

$$L_1 \geq \frac{2D(1-D)V_O T_S}{3r_{i1}\%I_{L1}} \tag{3}$$

The design of the capacitor mainly considers the voltage stress and maximum acceptable voltage ripple across it. The capacitors C_2,C_3, C_4, C_5 and $C_0$are obtained by taking voltage ripple as $r_{C2}\%V_{C2}$= 10%, $r_{c3}\%V_{C3}$= 10%,$r_{c0}\%V_{CO}$= 1% and $r_{c5}\%V_{C5}$= 1%. By substituting values to (4) , (5),(6),(7) and (8) capacitor values are approximated to 20μF for C_2 ,10μF for C_3, C_4, C_0 and C_5.

$$C_2 \geq \frac{(1+D)V_O T_S}{R(1-2D)r_{c2}\%V_{C2}} \tag{4}$$

$$C_3 \geq \frac{V_O T_S}{R{*}r_{c2}\%V_{c2}} \tag{5}$$

$$C_4 \geq \frac{V_0 T_S}{R{*}r_{c4}\%V_{c0}} \tag{6}$$

$$C_0 \geq \frac{DV_0 T_S}{R{*}r_{c0}\%V_{c0}} \tag{7}$$

$$C_5 \geq \frac{DV_0 T_S}{R{*}r_{c5}\%V_{c5}} \tag{8}$$

III. Simulations And Results

The multiple output single inductor boost converter is simulated in MATLAB/SIMULINK by choosing the parameters listed in Table 1. The switches are MOSFET with constant switching frequency of 30 kHz.

TABLE I

Simulation Parameters of Multiple Output Single Inductor Boost Converter

Parameters	Specifications
Input voltage (V_i)	30V
Output voltage (V_{o1},V_{o2},V_{o3})	170V,300V,80V
Switching frequency (f_s)	30kHz
Inductor (L_1)	1mH
Capacitor (C_1)	0.7mF
Capacitor (C_2)	10μF
Capacitor (C_3, $C_{4,}$)	10μF
Capacitor ($C_{0,}$ C_5)	10μF
Output resistance (R_1, $R_{2,}$&R_3)	360Ω

The switches are MOSFET with constant switching frequency of 30kHz. A DC input voltage of 30V and input current of 11A give the multiple outputs V_{01}, V_{02} and V_{03} of 170V,300V and 80V, the output current I_{01}, I_{02}, I_{03} of 2.2A, 0.6A and 12A for an output power of 250W. Fig.4 shows the input voltage and input current. Thus, voltage gain is obtained as 10. Fig.5 shows the multiple output and the output currents. The Fig.6 shows the voltage stress across the switches both switches share the voltage stress equally about 100V.

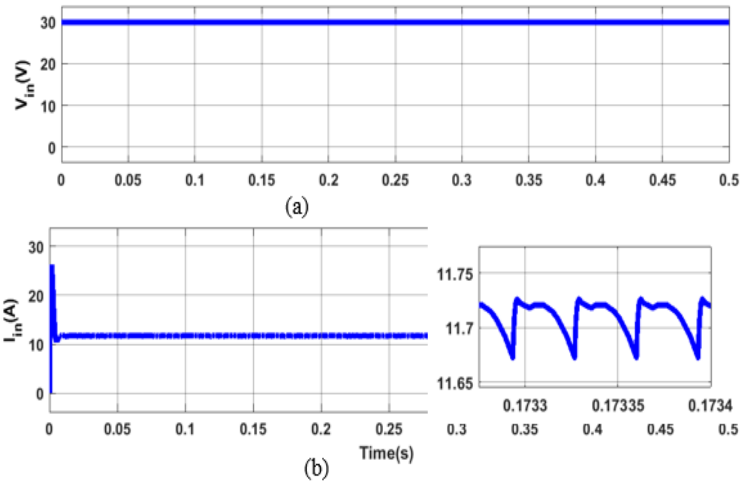


Fig. 4 (a) Input Voltage, (b) Input Current

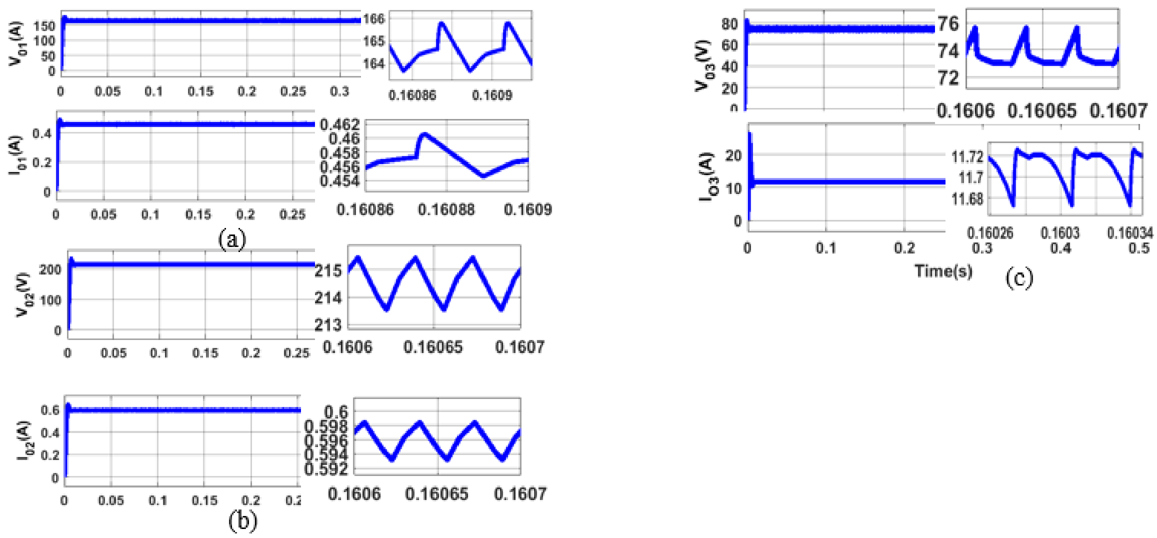


Fig. 5. Output Voltage and Output Current of (a) V_{01}& I_{01}, (b) V_{02} & I_{02}, (c) V_{03} & I_{03}

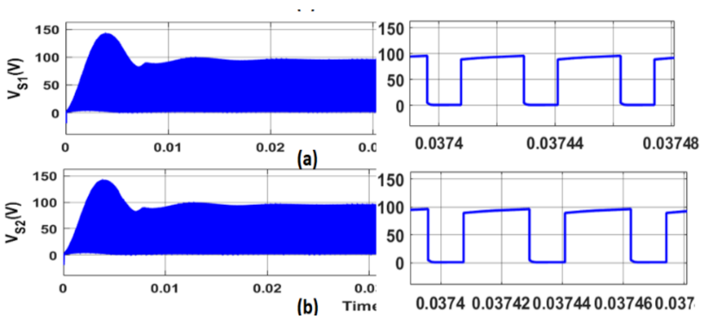


Fig.6 Voltage Across Switches (a) $S_1(V_{S_1})$, (b) $S_2(V_{S_2})$

IV. Performance Analysis

Efficiency of a power equipment is defined at any loadmaster ratio of the power output to the power input. Here the efficiency VS output power with R load and RL load for multiple output boost converter.91% and 90 %˙ Fig.7 shows is analysis. The variation of efficiency with power output is medium for both i.e. 250W. Fig.8 shows the voltage ripple Vs duty ratio from that analysis it is understood that the voltage ripple is comparitively reduced.

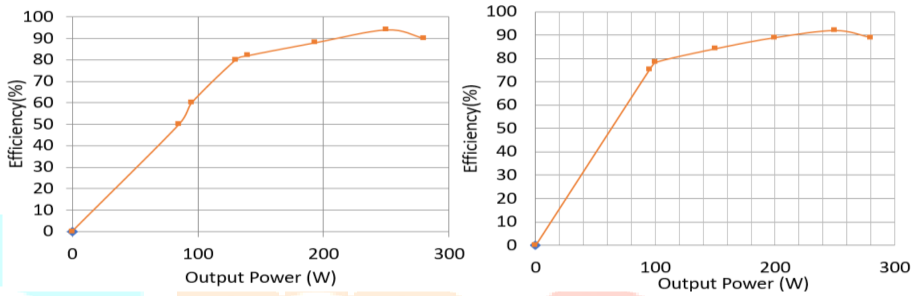


Fig. 7. Efficiency Vs Output Power for (a) R load, (b) RL load

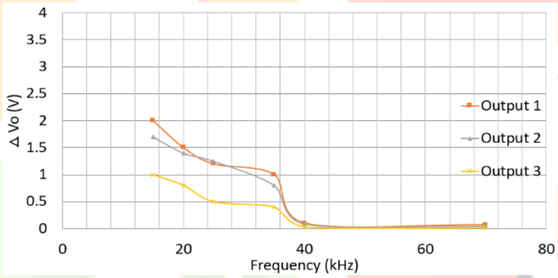


Fig. 8. Output voltage ripple Vs Duty ratio

V. Comparative Study

The comparison between multiple output boost converter and single inductor boost converter is given in table 2. On the comparison it can be observed that, keeping same values for input voltage 30V and switching frequency as 30kHz, the required output voltage is 170V, 300V and 80V.The multiple output is not present in other converters and the voltage ripple is less. Table 3 shows the component wise comparison between multiple output single inductor boost converter with other different type component. From the table it can be observed that, the number of components used moderately less.

TABLE II

Comparison between Proposed converter and single inductor boost converter

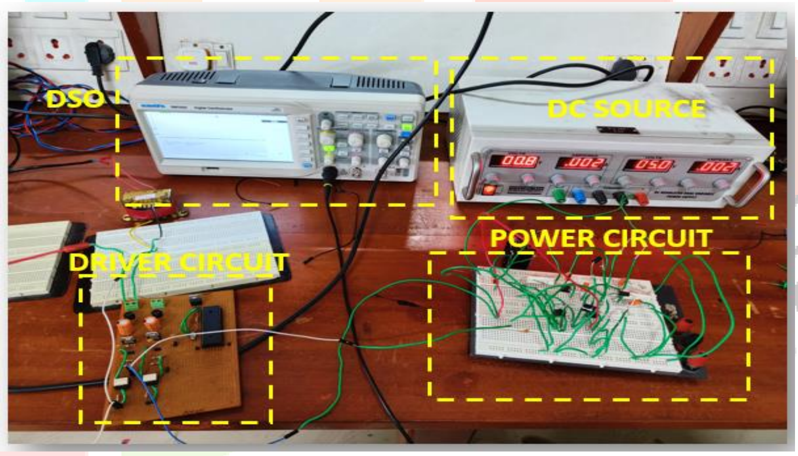
Parameter	Multiple Output Boost Converter	Single Inductor Boost Converter
Number of Switches	2	2
Number of Inductors	1	1
Number of Capacitors	6	4
Number of Diodes	6	5
Input Voltage (f_s= 30kHz)	30V	30V
Output Voltage	300V,176V,80V	300V
Voltage stress of Switches	S_1 =100V S_2 =100V	S_1 =100V S_2 =100V
Voltage stress of Diodes	D_1, D_2, D_3 – 100V D_4, D_0, D_5 – 150V	D_1, D_2, D_3 – 100V D_4, D_0 – 150V

TABLE III
Comparison between Multiple output -Single inductor boost converter & Other converters

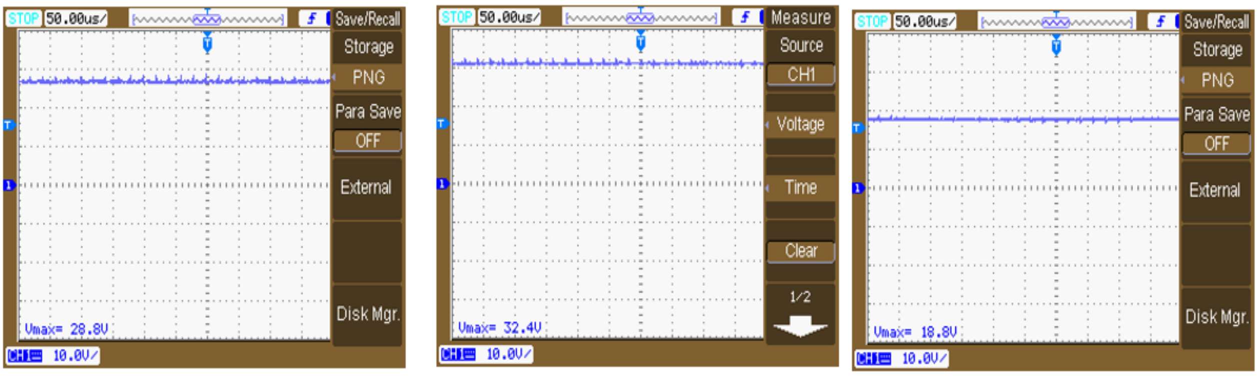
Parameters	Bidirectional DC-DC Converter	Hybrid Z-source Boost Converter	Quasi-Z source Boost Converter	Multiple Output-Single inductor boost converter
Switches	2	3	3	2
Inductors	4	3	3	1
Capacitors	5	5	6	6
Diodes	4	5	5	6
Total	15	16	17	15

VI. Experimental Setup With Results

For the purpose of implementing hardware, the input voltage is reduced to 5V and the switching pulses are generated using PIC16F877A controller. The switches are MOSFET IRf540 and diodes are 10A10 NSL. Driver circuit is implemented using TLP250H, which is optocoupler used to isolate and protect the microcontroller from any damage and also to provide required gating to turn on the switches. Experimental setup of multiple output single inductor boost converter is shown in Fig.10. Input is 5V Dc supply is given from the DC source. Switching pulses are taken from the PIC controller to driver circuit. Thus , three multiple output is obtained about 50V, 28.8V and 12V respectively with frequency of 30kHz. Output voltage of inverter is taken from the DSO oscilloscope which is shown in the Fig.9.



(a)



(b)

Fig. 9. (a) Experimental Setup, (b) Output Voltage of Proposed Inverter

VII. Conclusion

The multiple output single inductor boost converter provides numerous advantages in the field of photovoltaic applications. As the energy consumption is increasing day by day, conventional energy resources can be replaced by non-conventional energy resources. Mainly a PV system can be implemented for domestic and industrial applications. Although to meet the required output voltage at the grid side a boost converter is needed to interface between PV cells and inverter. The multiple outputs ingle inductor boost converter has high an efficiency of 92% at the specified duty cycle. The output voltage ripple and output current ripple is lower for this converter. The converter has wide voltage conversion ratio with continuous input current and also have high voltage step-up gain. It provides a voltage gain of 10 for an input voltage of 30V. The common ground enhances the performance of the converter by reducing the leakage current and eliminating the EMI issues and the converter produce a positive output. This converter has simple topology and it can be used in renewable energy applications and battery charging. Moreover, multiple outputs are taken from the circuit, which make the circuit suitable for multiple purposes at the same time. Hardware is implemented using PIC16F877A micro-controller. The prototype converter section is tested and the results are experimentally verified. The results prove the analysis and performance of the converter. The project was able to achieve all its objectives.

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