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Simulation and Steady State Analysis of a Non-isolated Diode Rectifier-fed DC-DC Boost Converter with High Static Voltage Gain

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ABSTRACT

This paper presents the simulation and analysis of a non-isolated step-up DC-DC converter operating in continuous inductor current mode with fixed switching frequency. The proposed converter proves better steady state performance in terms of improved voltage gain compared to the conventional boost configuration. The suggested two stage converter topology is fed by an uncontrolled diode bridge rectifier for which the sinusoidal input AC voltage is (50/ $\sqrt{2}$) V (rms). The design of the converter is such that the input AC voltage of (50/ $\sqrt{2}$) V (rms) is stepped up to around 256 V (DC) at the load end for the duty ratio value of 0.8. The performance of the proposed converter configuration is validated through simulation in Matlab/Simulink platform. The open-loop configuration provides higher constant output voltage profile compared to the conventional boost topology. The output voltage and current profiles show reduced settling time with almost no overshoot. The output voltage ripple is reduced to lower value. The suggested configuration ensures that the voltage-current stress across the switches is also reduced.

KEYWORDS: *Continuous inductor current mode, DC-DC converter, Duty ratio, Matlab/Simulink, Open-loop configuration, Voltage-current stress.*

I. INTRODUCTION

There are two different classifications of high voltage gain DC-DC converter topologies such as non-isolated and isolated configurations [1]-[4]. Due to the use of transformer in the isolated converter structure, there are certain disadvantages such as low power density, slightly complicated structure and control, and easy saturation of magnetic flux [5]-[9]. The nonisolated DC-DC conversion schemes are desirable for certain applications in view of improved efficiency and power density [10]-[11]. Now a days, the most commonly used approach of DC-DC conversion is to employ two stages; a non-isolated DC-DC converter can be used as the first stage and an isolated or non-isolated DC-DC converter may be used as the second stage of conversion. The second harmonic voltage effect that is reflected at the output stage because of single phase AC mains input is eliminated due to the use of first stage [12]-[14]. The complexity, cost and space can be reduced when only a single output is sensed and regulated by feedback control. Usually, in the front end, an uncontrolled diode bridge rectifier circuit is used to convert AC mains voltage to unregulated DC voltage [15]-[16]. In the present work, two stages of DC-DC conversion such as boost power stage and conventional boost stage are used to improve and regulate the DC output voltage. The proposed two-stage conversion scheme is a cost-effective approach in high power applications, where the input current is forced to follow the input voltage due to an active power factor correction stage at the front-end, to ensure the elimination of input current harmonics. Also, a loosely regulated high voltage DC established at the output of the power factor correction stage serves as the input voltage to a conventional DC/DC converter to produce a tightly regulated high DC output voltage [17]-[19].

Some authors proposed a comprehensive review of voltage-boosting techniques, topologies, and applications of DC-DC boost converters [20]. Advanced high-voltage-gain DC-DC boost converter topologies and single switch AC/DC converter with extended voltage conversion range are suggested in [21]-[23] for renewable energy and SMPS applications. The soft-switched CCM boost converters having voltage conversion ratio twice that of the conventional boost converter for high-power applications are better analyzed in [24].

The work presented in this paper gives the steady state behavior of a high voltage conversion ratio DC-DC conversion scheme consisting of two stages. The first stage converts a low level rectified DC voltage is converted into a high level DC voltage in the first stage using a boost inductor and switch elements [25]. This stage is called boost power stage whose output is given as input to the second conventional boost converter stage which is capable to produce an increased DC output voltage than the first stage across a resistive load.

The research work presented in this paper is structured with four sections including the introduction part. The steady state behavior of the proposed DC-DC converter operating in continuous inductor current mode has been explained in section 2. The section 3 illustrates the simulation analysis of the suggested converter configuration in Matlab/Simulink environment and the corresponding results and discussions. The conclusion of the proposed work is given in section 4.

II. Proposed Converter Configuration and its Modes of Operation

The power circuit topology of the proposed non-isolated rectifier-fed two-stage DC-DC boost converter operating in continuous inductor current mode is shown in Fig.1. A DC output voltage is obtained from a 50 Hz single phase AC supply using a diode bridge rectifier. A capacitor C is used to filter out the ripples in the DC voltage. The first stage of DC-DC conversion scheme receives this filtered DC output as the input. The first stage is called boost power stage consisting of components such as a suitably designed boost inductor, a boost rectifier, a boost pre-charge diode, and a boost (MOSFET) switch. The filter inductor on the input side of the boost stage provides a smooth continuous input current waveform. The ripple present in the input current is typically 20-40% of the average input current. The filter inductor's size and maximum current are determined using the Equations (1) and (2) shown below [25]:

$$L_b = \frac{1}{\%Ripple}\frac{V_{ac.\min}^2}{P_0}\left(1-\frac{\sqrt{2}V_{ac.\min}}{V_0}\right)\left(\frac{1}{f_s}\right) \tag{1}$$

$$I_{L.\max} = \frac{\sqrt{2}P_0}{V_{ac.\min}}\left(1+\frac{\%Ripple}{2}\right) \tag{2}$$

The two active switches S_b and S_1 in the proposed converter configuration shown in Fig. 1 are turned on or off together. Accordingly, two modes of operation for the converter are explained as shown below:

Mode-I operation of the converter:

During Mode-I operation of the converter, both the switches S_b and S_1 are turned on. The diode D_b gets forward biased and the diodes D_{br} and D get reverse biased. The two inductors L_b and L_1 are connected in parallel across the DC output of rectifier (V_{dc}) and the capacitor C_1 discharges the energy through the load R_L. The inductors are charged and hence absorb energy from V_{dc}. This Mode-I operation is explained as shown in Fig. 2. The two inductors L_b and L_1 carry equal currents $(I_{Lb} = I_{L1} = I_L)$ since they have the same values and are connected across the same input DC source V_{12} = V_{dc}. The energy absorbed (W_L^{ON}) by the inductors during the turn-on period of the switches S_b and S_1 is given by Equation (3).

$$W_L^{ON} = V_{dc} \times I_L \times D \times T_s \tag{3}$$

Where, D is the duty cycle of Pulse Width Modulation (PWM) pulse; T_s is the PWM period.

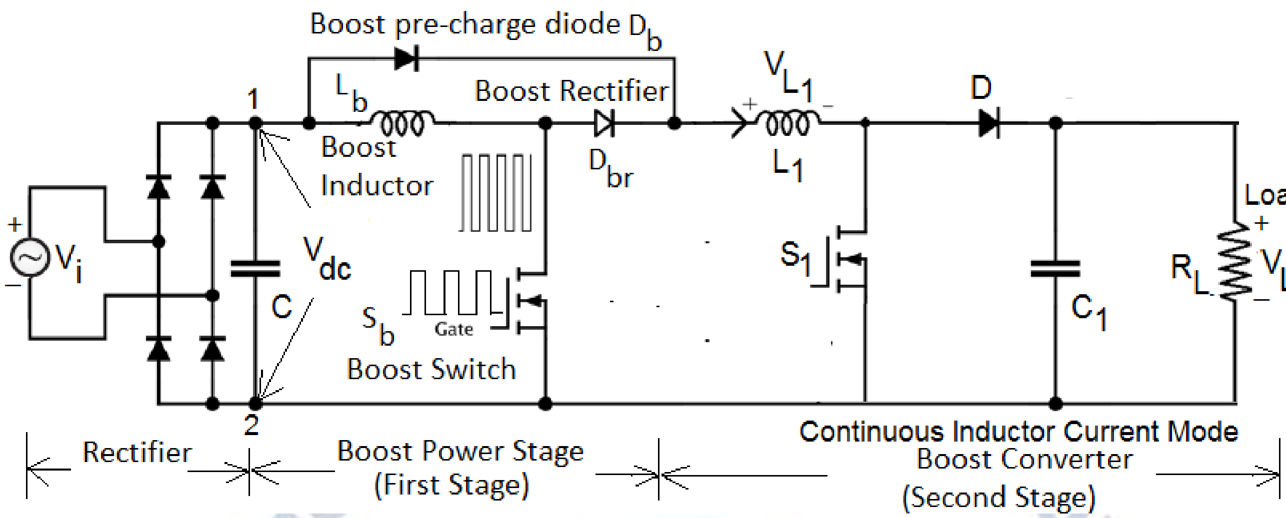

Fig. 1 Configuration of the proposed rectifier-fed non-isolated two-stage DC-DC boost converter

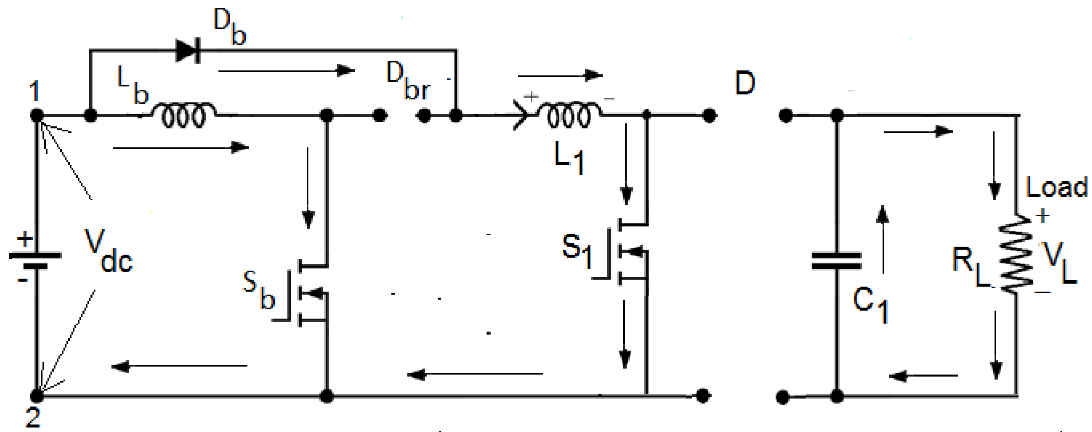

Fig. 2 Mode-I operation of the proposed converter

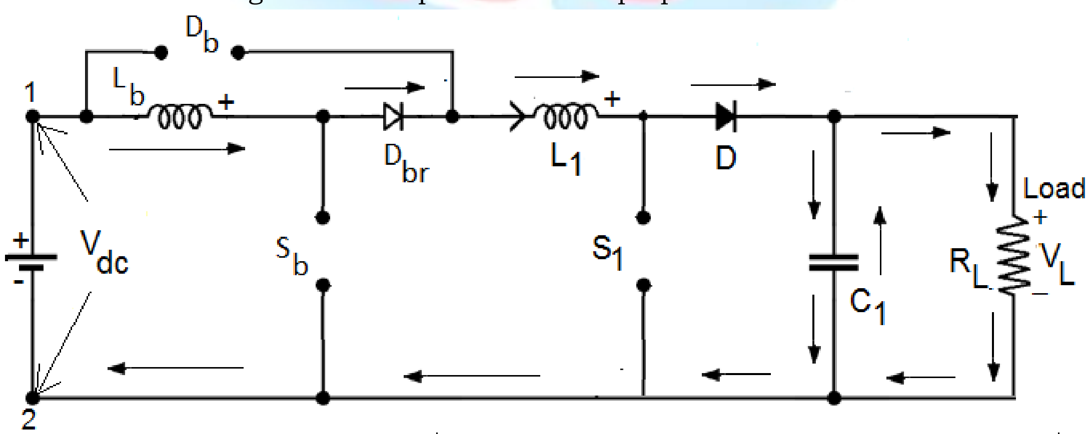

Fig. 3 Mode-II operation of the proposed converter

Mode-II operation of the converter:

During Mode-II operation of the converter, both the switches S_b and S_1 are turned off. So both the switches will act as open circuit. The diodes D_{br} and D get forward biased. The diode D_b gets reverse biased. The current flow direction is as indicated in Fig. 3. The two inductors are now connected in series to provide the energy to the load R_L and charge the output capacitor C_1. The energy released (W_L^{OFF}) by the two inductors during the turn-off period of the switches S_b and S_1 is given by Equation (4).

$$W_L^{OFF} = \left(\frac{V_L - V_{dc}}{2}\right) \times I_L \times (1-D) \times T_s \qquad (4)$$

The law of conservation of energy states that the energy can neither be created nor be destroyed. Hence, the Equations (3) and (4) are equal.

$$V_{dc} \times I_L \times D \times T_s = \left(\frac{V_L - V_{dc}}{2}\right) \times I_L \times (1-D) \times T_s$$

By simplifying the above equation, the voltage gain (G_C) of the proposed converter is obtained as shown in Equation (5).

$$G_C = \frac{V_L}{V_{dc}} = \frac{1+D}{1-D} \quad (5)$$

The typical steady-state waveforms of the suggested converter configuration operating under continuous inductor current mode are presented in Fig. 4.

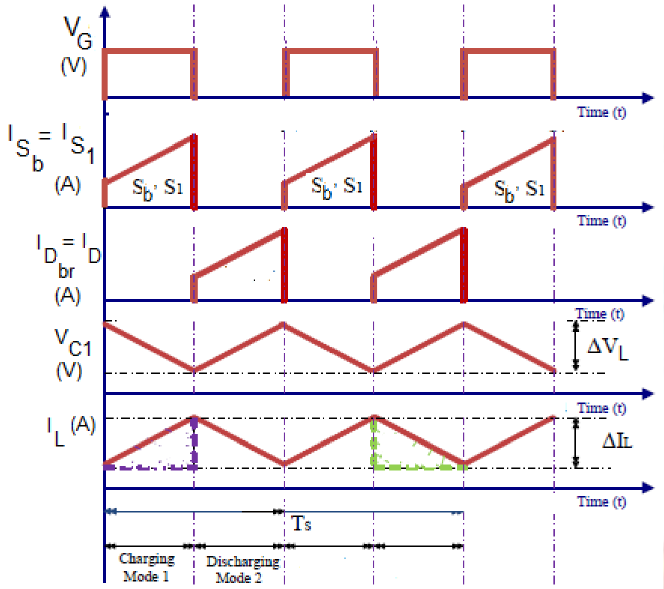

Fig. 4 Typical steady state waveforms of the converter

III. Simulation Results and Discussion

The proposed converter model has been developed and simulated in Matlab/Simulink platform. The simulation diagram of the proposed two-stage converter is shown in Fig. 5. The circuit components are obtained from Sim Power System library. Multi-plot and Scope are used for viewing the simulation results. The proposed rectifier-fed two-stage boost converter is simulated at a switching frequency of 50 kHz. The values of circuit components for the simulation are selected based on the design considerations and are listed in Table I shown below. Table II lists the specifications of the proposed converter. The proposed converter circuit is simulated using solver 'ode 45' of variable-step type. The Simulink uses a graphical user interface (GUI) for solving process simulations. Discrete state variable model of sampling time $T_S = 4e^{-005}$ sec. is used for simulation. The gating pulses to the switches S_b and S_1 are shown in Fig. 4. The various waveforms for the proposed converter are shown in Fig. 6 – Fig. 9 respectively. The output DC voltage is compared with that of the conventional boost converter. The simulation results demonstrate that the proposed converter shows improved voltage gain compared to that of conventional boost converter.

Table I: Simulation parameters of the proposed converter

Circuit components	Values
Boost Inductor (L_b)	150 mH
Inductor (L_1)	150 mH
Filter Capacitor (C)	100 µF
Output Capacitor (C_1)	25 µF
Load Resistor (R_L)	96 Ω
Duty Ratio of the switches (D)	0.8

Table II: Specifications of the proposed converter

Specifications	Values
Input AC voltage (V_i)	$(50/\sqrt{2})$ V (rms)
Output voltage (V_L)	256 V (DC)
Switching frequency (F_s)	50 kHz
Maximum output power (P_0)	160 W
Average output current (I_L)	2.5 A

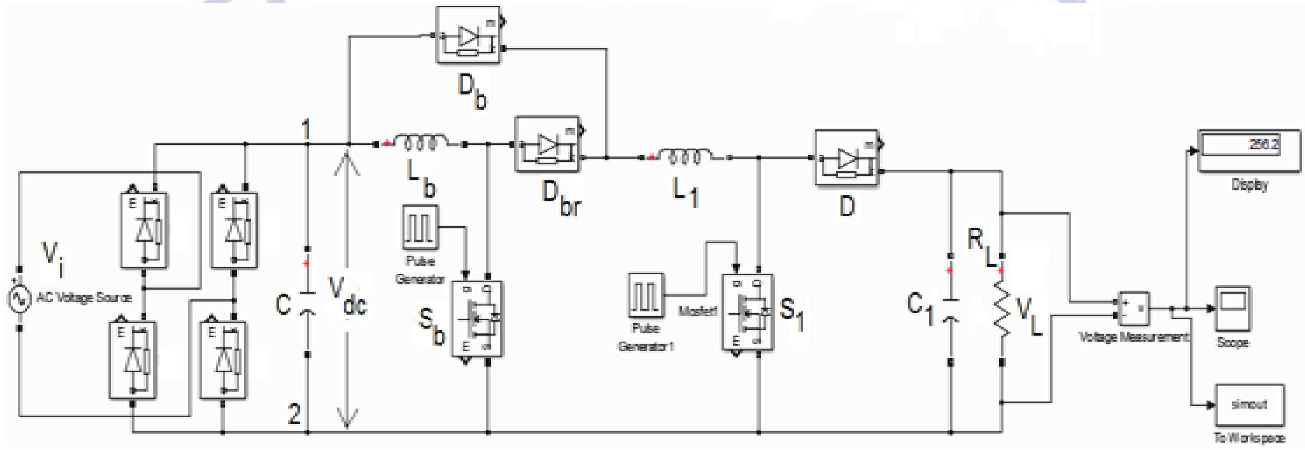

Fig. 5 Simulation diagram of the proposed DC-DC converter configuration

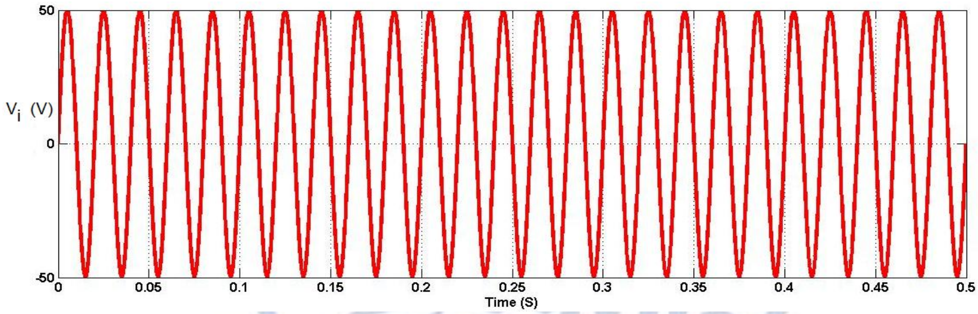

Fig. 6 Input AC voltage waveform (V_i) for the proposed converter

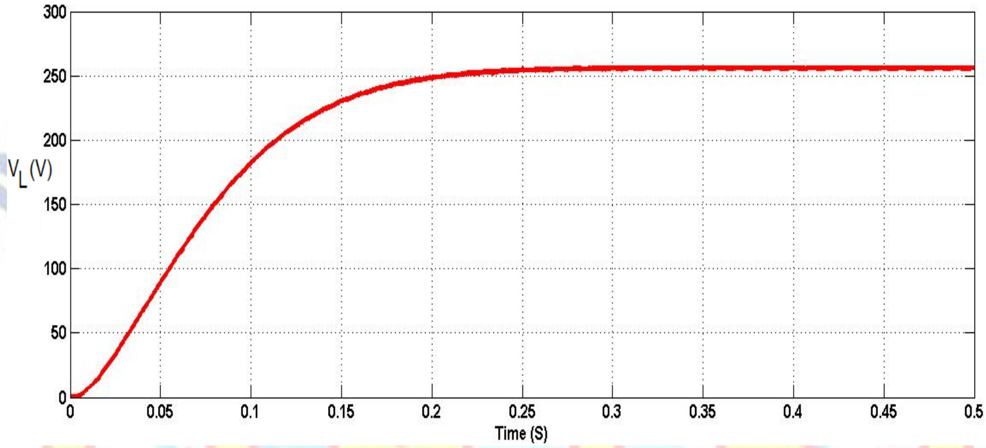

Fig. 7 Output voltage waveform (V_L) of the proposed converter for duty cycle D = 0.8

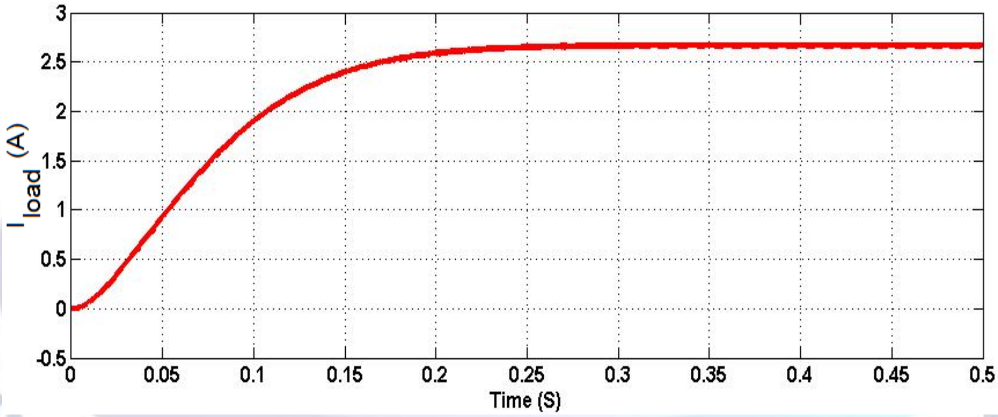

Fig. 8 Output current waveform (I_{load}) of the proposed converter for duty cycle D = 0.8

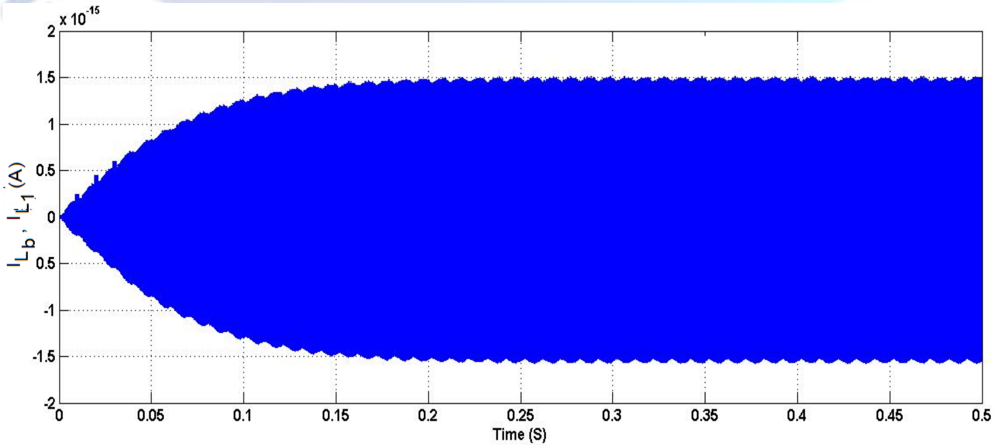

Fig. 9 Inductor current waveform of the proposed converter for duty cycle D = 0.8

IV. Conclusion

This paper presents the steady state behavior of a non-isolated rectifier-fed DC-DC boost converter. The time-domain simulations have been are carried out in Matlab/Simulink environment to validate the effectiveness of the proposed converter. The results demonstrate that the proposed converter configuration has the capability to produce an output voltage which is almost nine times the DC input voltage for a particular duty cycle. Hence, the proposed converter topology can provide the improved voltage gain. In the proposed converter configuration, the switches are turned on and off together by the conventional Pulse Width Modulation technique. The proposed converter configuration is compared with that of the existing conventional DC-DC boost topology which can give output DC voltage only five times the input DC voltage. Moreover, in the proposed non-isolated converter topology, the switching losses, the voltage stress and the current stress of the switches are significantly reduced. The high DC voltage gain and slightly improved efficiency can be realized using the non-isolated converter configuration suggested in this paper.

References

[1] F. Evran, and M. T. Aydemir, “Isolated high step-up dc-dc converter with low voltage stress”, *IEEE Transactions on Power Electronics*, Vol. 29, No. 7, pp. 3591-3603, 2014.

[2] F. L. Tofoli, D. d. C. Pereira, W. J. de Paula, and D. D. S. Oliveira Junior, “Survey on non-isolated high-voltage step-up dc-dc topologies based on the boost converter”, *IET Power Electronics*, Vol. 8, No. 10, pp. 2044-2057, 2015.

[3] A. Chub, D. Vinnikov, F. Blaabjerg, and F. Z. Peng, “A review of galvanically isolated impedance-source DC-DC converters”, *IEEE Transactions on Power Electronics*, Vol. 31, No. 4, pp. 2808-2828, 2016.

[4] W. Li and X. He, “Review of nonisolated high-step-up dc/dc converters in photovoltaic grid-connected applications”, *IEEE Transactions on Industrial Electronics*, Vol. 58, No. 4, pp. 1239–1250, 2011.

[5] A. Ajami, H. Ardi, and A. Farakhor, “A novel high step-up DC/DC converter based on integrating coupled inductor and switched-capacitor techniques for renewable energy applications”, *IEEE Transactions on Power Electronics*, Vol. 30, No. 8, pp. 4255-4263, 2015.

[6] H. Liu, H. Hu, H. Wu, Y. Xing, and Issa Batarseh, “Overview of high-step-up coupled-inductor boost converters”, *IEEE Journal of Emerging and Selected Topics in Power Electronics*, Vol. 4, No. 2, pp. 689-704, 2016.

[7] L. Changyong, Z. Jinbin, M. Ling, Z. Mingjie, and L. Yutong, “A high step-down DC-DC converter”, *Transaction of China Electrotechnical Society*, Vol. 34, pp. 4264-4271, 2019.

[8] M. R. Banaei and H. A. F. Bonab, “A high efficiency nonisolated buck-boost converter based on ZETA converter”, *IEEE Transactions on Industrial Electronics*, Vol. 67, No. 3, pp. 1991-1998, 2020.

[9] A. Sowmya and D. Murali, “A high voltage gain step-up resonant DC-DC converter topology with reduced switch count”, *International Journal for Modern Trends in Science and Technology*, Vol. 5, No. 12, pp. 26-31, 2019.

[10] S. Saravanan and N. Ramesh Babu, “A modified high step-up non-isolated DC-DC converter for PV application”, *Journal of Applied Research and Technology*, Vol. 15, No. 3, pp. 242-249, 2019.

[11] W. Hanqing, G. Arnaud, and H. Daniel, “A review of DC/DC converter-based electrochemical impedance spectroscopy for fuel cell electric vehicles”, *Renewable Energy*, 141(C), 124–138, 2019.

[12] J. Y. Zhu and B. Lehman, “Control loop design for two-stage DC-DC converters with low voltage/high current output”, *IEEE Transactions on Power Electronics*, Vol. 20, No. 1, pp. 44-55, 2005.

[13] S. Abe, J. Yamamoto, T. Zaitsu, and T. Ninomiya, “Extension of bandwidth of two-stage DC-DC converter with low-voltage/high-current output”, *Proceedings of IEEE 34th Annual Conference on Power Electronics Specialist*, Vol. 4, pp. 1593-1598, 2003.

[14] L. H. Dixon, Jr., “High power factor preregulators for off-line power supplies”, *Unitrode Switching Regulator Power Supply Design Seminar Manual*, Paper 12, SEM-700, 1990.

[15] D. Murali and S. Annapurani, “A high voltage gain rectifier-fed two-stage step-up DC-DC converter with PI controller”, *International Journal of Engineering Applied Sciences and Technology*, Vol. 4, No. 8, pp. 160-164, 2019.

[16] S. Annapurani and D. Murali, “Parallel-charge-series-discharge inductor-based voltage boosting technique Applied to a rectifier-fed positive output DC-DC converter”, *Journal of Applied Research and Technology*, Vol. 18, No. 5, pp. 229-244, 2020.

[17] J. Zhang, M. M. Jovanovic, and F. C. Lee, “Comparison between CCM single-stage and two-stage boost PFC converters”, *Proceedings of 14th Annual Applied Power Electronics Conference and Exposition*, 1999.

[18] C. Piao, H. Qiao, and C. Teng, “Digital control algorithm for two-stage DC-DC converters”, *Energy Procedia*, Vol. 16, pp. 265-271, 2012.

[19] P. Wen, C. Hu, H. Yang, L. Zhang, C. Deng, Y. Li, and D. Xu, “A two-stage DC/DC converter with wide input range for EV”, *Proceedings of International Power Electronics Conference*, 2014.

[20] M. Forouzesh, Y. P. Siwakoti, S. A. Gorji, F. Blaabjerg, and B. Lehman, “Step-up DC-DC converters: A comprehensive review of voltage-boosting techniques, topologies, and applications”, *IEEE Transactions on Power Electronics*, Vol. 32, No. 12, pp. 9143-9178, 2017.

[21] X. Hu and C. Gong, “A high voltage gain DC-DC converter integrating coupled-inductor and diode-capacitor techniques”, *IEEE Transactions on Power Electronics*, Vol. 29, No. 2, pp. 789-800, 2014.

[22] K. C. Tseng and C. C. Huang, “High step-up, high efficiency interleaved converter with voltage multiplier module for renewable energy system”, *IEEE Transactions on Industrial Electronics*, Vol. 61, No. 3, pp. 1311-1319, 2014.

[23] L. Sri Sivani, B. Nagi Reddy, K. Subba Rao, and A.Pandian, “A new single switch AC/DC converter with extended voltage conversion ratio for SMPS applications”, *International Journal of Innovative Technology and Exploring Engineering*, Vol. 8, No. 3, pp. 68-72, 2019.

[24] S. Park and S. Choi, “Soft-switched CCM boost converters with high voltage gain for high-power applications”, *IEEE Transactions on Power Electronics*, Vol. 25, No. 5, pp. 1211-1217, 2010.

[25] S. A. Rahman, F. Stuckler, and K. Siu, “PFC boost converter design guide”, *Infineon Application Note*, pp. 1-30, 2016.