Open Loop Analysis of a High Performance Input Switched Single Phase AC-DC Boost Converter

Khadiza Akter[1], Firuz Ahamed Nahid[2], Nafiul Islam[3]

Senior Lecturer, Department of EEE, International University of Business Agriculture and Technology Dhaka, Bangladesh

Abstract

A new topology of input switched single - phase AC-DC Boost converter with low input current THD and high input power factor has been proposed. In order to provide high voltage step-up ratio which is required for high step-up applications like in micro generators, the conventional boost converters with bridge rectifier configuration are not efficient. Instead of using a rectifier configuration followed by a boost DC-DC converter, the input of the rectifier is chopped at high frequency during the positive and negative cycle by a single switch to get a step-up AC-DC conversion. The proposed circuit shows improvement in the Total Harmonic Distortion (THD) of the input current using a small input current filter. Analysis and simulation results of the circuits were conducted using PSIM 9.1 environment. Input power factor and the efficiency of the proposed converter were found satisfactory without any feedback controller compared to the conventional circuit. The proposed input switched boost converter showed improved performance compared to the conventional converter.

Keywords — *Bridgeless Rectifier, Boost Topology, Power Factor Correction (PFC), Total Harmonic Distortion (THD), Efficiency, AC-DC Conversion, Voltage gain.*

I. INTRODUCTION

AC-DC converter with high power quality is of vital importance in applications like renewable energy sources or power supplies for modern day appliances. Alternators in power stations generate AC output voltage which is transmitted and distributed for various applications, therefore efficient conversion of AC-DC is required. However, it is very difficult to satisfy both the high voltage conversion ratio and high efficiency at once [1]-[4]. The output voltage of micro generators is AC with a low voltage level in the range of a few hundred million volts, but electronic loads require much higher DC voltage. Hence, power electronic converters are used to condition the outputs of the micro generators and to provide the required DC bus to the loads. Conventional AC-DC converters suffer from distorted input current, low power factor, and low efficiency. To reduce harmonic distortions in power lines and improve the transmission efficiency, various power factor correction (PFC) techniques have been proposed. The preferable type of PFC technique is active PFC since it makes the load to behave like a pure resistor, leading to a near-unity power factor, generating negligible harmonics in the input line current. Most of the presented bridgeless topologies so far implemented a boost configuration, referred to as dual boost PFC rectifier, because of its low cost and high performance in terms of efficiency, power factor, and simplicity. Bridgeless PFC boost rectifier implementation has been proposed along with their performance comparison, with the conventional PFC boost rectifier [5]-[8].

Most active PFC circuits as well as switched-mode power supplies in the market today comprises of a front-end bridge rectifier, followed by a high-frequency DC-DC converter such as a buck, boost, buck-boost, Cuk, SEPIC, ZETA and flyback converter[9]-[16]. The conduction loss caused by the high forward voltage drop of the diode bridge degrades the overall system efficiency as the power level increases and the heat generated within the bridge rectifier may destroy the individual diodes. Hence, it becomes necessary to utilize a bridge rectifier with higher current handling capability or heat dissipating characteristics [17]-[18].

In this paper a new topology of input switched single-phase AC-DC boost converter with high performance has been proposed. Section II of this paper deals with the proposed boost AC-DC converter along with its principle of operation. Section III deals with the results and simulation showing the comparison of performances under duty cycle and load variation between the conventional and proposed boost converter. The proposed converter offers improved performance compared to the conventional boost converters

II. PROPOSED CIRCUIT CONFIGURATION AND OPERATION

The boost converter is one of the most widely used step-up converters which provides a high voltage at the load side compared to the input voltage. Conventional AC-DC boost converter as shown in

Fig. 1 suffers from high diode losses in a bridge configuration, low efficiency, low power factor and high THD in input current. Proposed boost topology based AC-DC converters shown in Fig. 2 can rectify both positive and negative half cycle of the input eliminating the requirement of bridge configuration of diodes. In the positive half cycle current flows through inductors L1, diodes D1 and D3, switch S, capacitor Co and load RL while during the negative half cycle, current flows through inductor L2, diodes D2 and D4, switch S, capacitor Co and load RL.

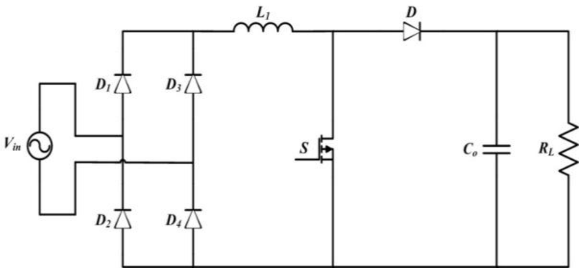


Fig 1: Conventional AC-DC Boost Converter.

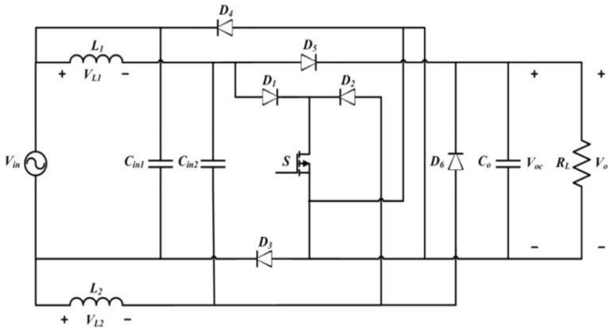


Fig 2: Proposed AC-DC Boost Converter.

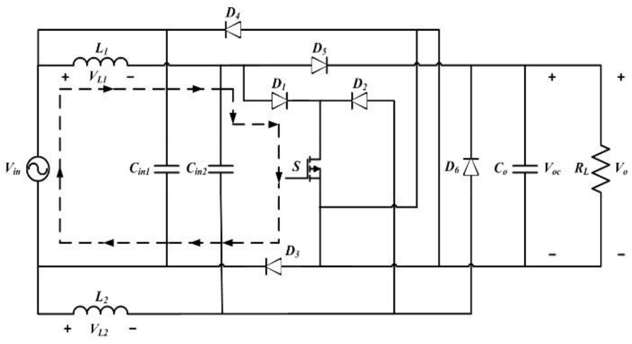


Fig 3: Positive half cycle of the input voltage when switch S is on (Mode 1).

The operation of the proposed circuit as shown in Fig. 3,4,5,6 can be explained by four modes of conduction along with the direction of current flow. Mode 1 and mode 2 shows the direction of current flow through the circuit during the positive half cycle of the input voltage when the switch S, is on and off respectively as shown in Fig. 3 and Fig. 4. Mode 3 and mode 4 shows the direction of current flow through the circuit during the negative half cycle of the input voltage when the switch S is on and off as shown in Fig. 5 and Fig. 6 respectively. During both the positive and negative cycle of the supply, the energy transferred to the load is unidirectional, thus AC-DC conversion is achieved.

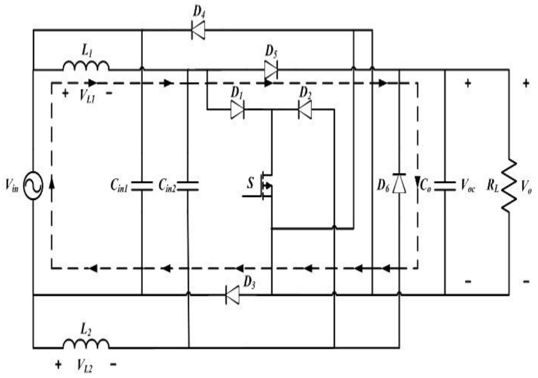


Fig 4: Positive half cycle of the input voltage when switch S is off (Mode 2).

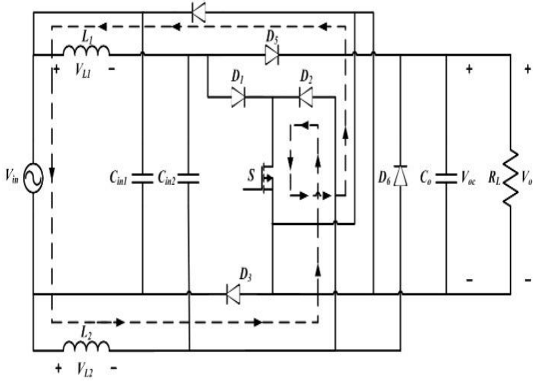


Fig 5: Negative half cycle of the input voltage when switch S is on (Mode 3).

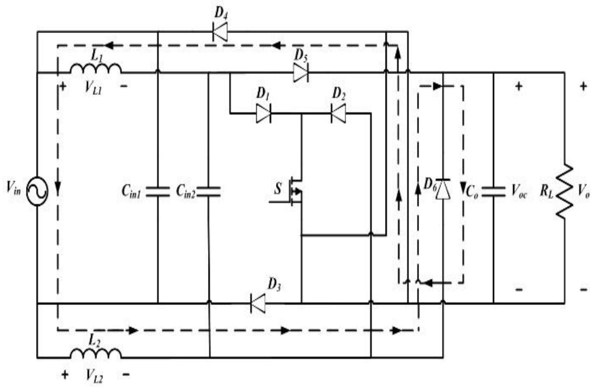


Fig 6: Negative half cycle of the input voltage when switch S is off (Mode 4).

III. RESULT AND SIMULATION

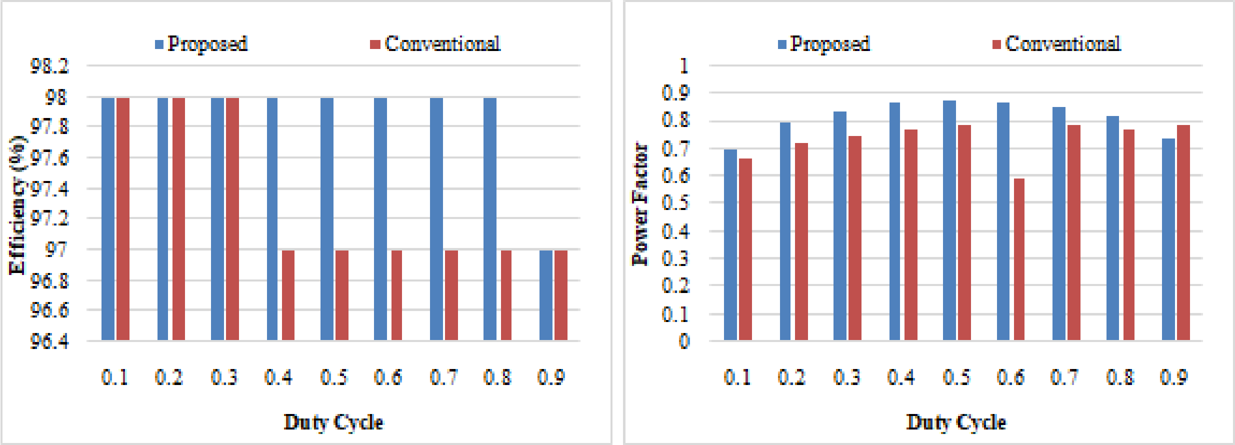
The simulation of the conventional and proposed boost AC-DC converter was performed using PSIM 9.1 environment. The design parameters used during simulation are given in Table I. In Table II, both conventional and proposed single phase AC-DC boost converter circuits were subjected to duty cycle variations at a fixed load of 100Ω and constant switching frequency of 5KHz, whereas in Table III, the circuit performance under load variation was conducted for both conventional and proposed converter for the switching frequency of 5 kHz at 50% duty cycle and the performance is monitored in terms of percentage efficiency, input power factor, total harmonic distortion (THD) of the input current, and voltage gain. It is evident from the table that the proposed converter shows better performance than the conventional converter with respect to the measured parameters.

TABLE II
Specification of design parameters

Parameters	**Value**
Input voltage (Vin)	220V
Switching Frequency (f)	5kHz,
Inductor (L1,L2)	1.5mH
Input Capacitor (Cin1)	4.5μF
Input Capacitor (Cin2)	4.5μF
Output Capacitor(C0)	220uF
Load Resistor (RL)	100Ω

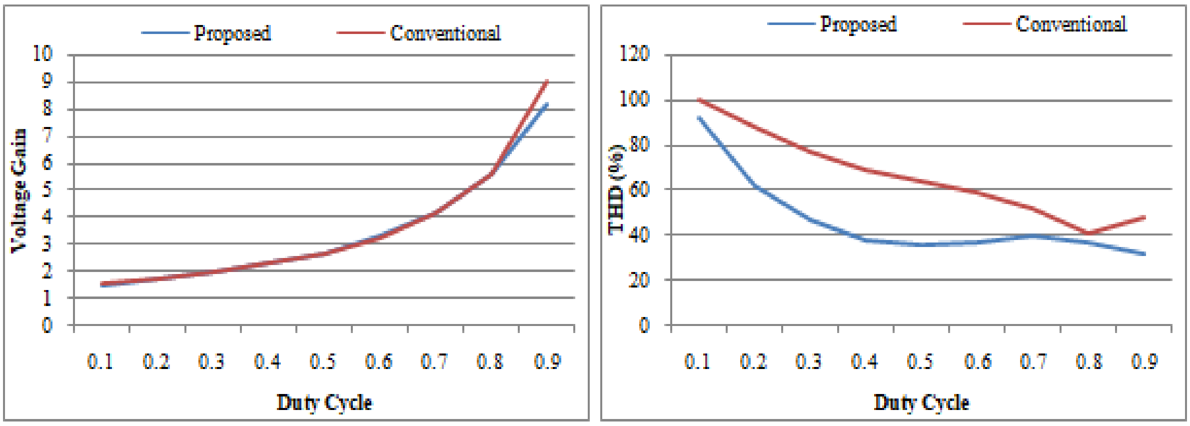
TABLE III
Performance comparison under duty cycle variation

Duty Cycle	**Proposed**				**Conventional**			
	Efficiency (%)	**THD (%)**	**Power Factor**	**Voltage Gain**	**Efficiency (%)**	**THD (%)**	**Power Factor**	**Voltage Gain**
0.1	98	92	0.7	1.5	98	100	0.67	1.53
0.2	98	62	0.8	1.72	98	88	0.72	1.72
0.3	98	47	0.84	1.98	98	77	0.75	1.92
0.4	98	38	0.87	2.31	97	69	0.77	2.26
0.5	98	36	.88	2.71	97	64	0.79	2.6
0.6	98	37	0.87	3.34	97	59	0.59	3.2
0.7	98	40	0.85	4.2	97	52	0.79	4.1
0.8	98	37	0.82	5.6	97	41	0.77	5.52
0.9	97	32	0.74	8.2	97	48	0.79	9.0



(a) (b)

Fig 7: Comparison between conventional and proposed boost converter (a) conversion efficiency, (b) power factor.



(c) (d)

Fig 8: Comparison between conventional and proposed boost converter (c) voltage gain, (d) total harmonic distortion u under duty cycle variation.

TABLE IV
Performance comparison under load variation

Load	Proposed Circuit				Conventional Circuit			
	Efficiency (%)	THD (%)	Power Factor	Voltage Gain	Efficiency (%)	THD (%)	Power Factor	Voltage Gain
50	99	49	0.81	2.63	98	62	0.80	2.61
70	98	44	0.88	2.67	98	64	0.80	2.64
90	98	38	0.88	2.77	98	64	0.80	2.66
110	98	34	0.87	2.78	97	64	0.78	2.68
130	97	35	0.86	2.88	97	63	0.76	2.70
150	97	36	0.85	3.03	96	63	0.75	2.72

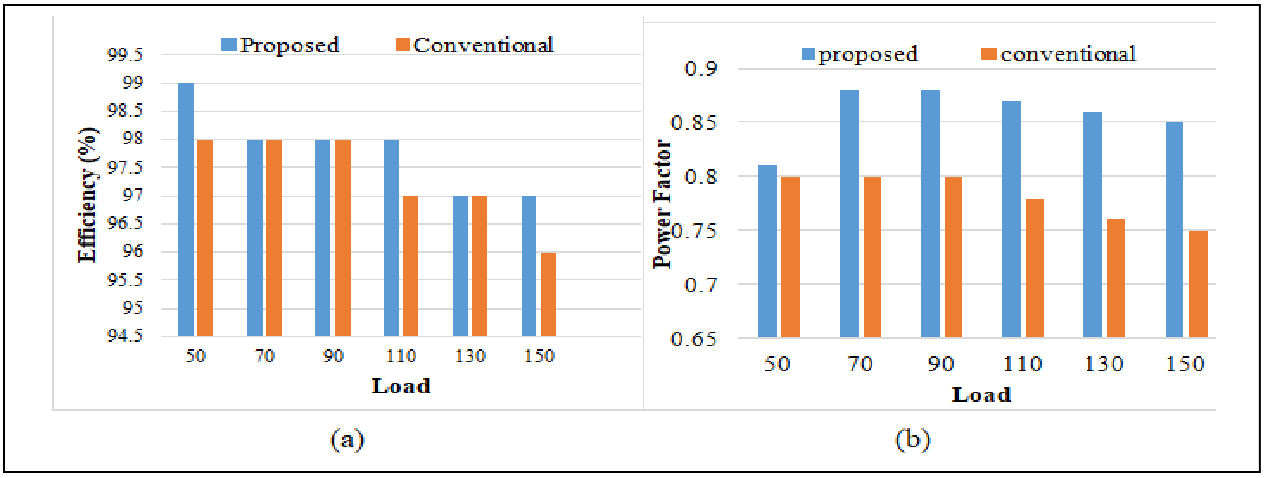
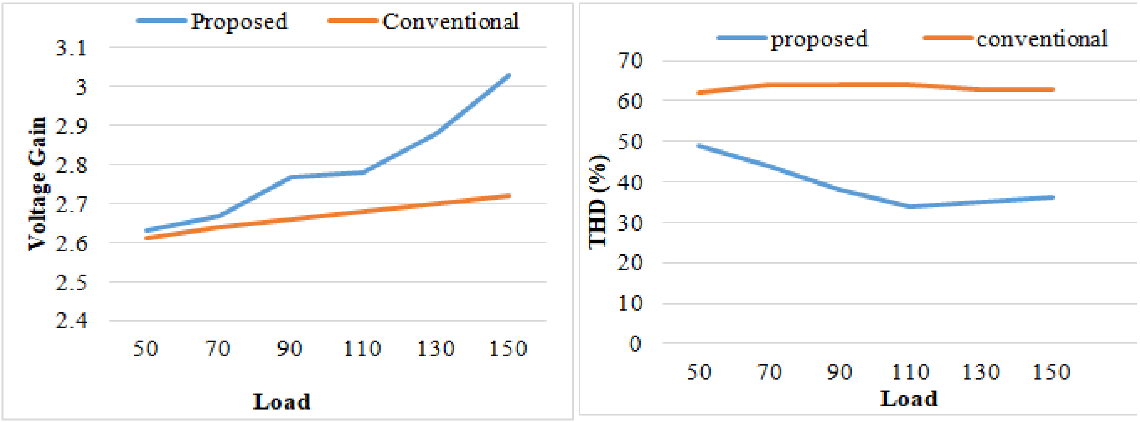


Fig 9: Comparison between the conventional and proposed boost converter (a) conversion efficiency, (b) power factor.

Fig 10: Comparison between the conventional and proposed boost converter (c) voltage gain, (d) total harmonic distortion under load variation.



(c) (d)

IV. CONCLUSION

A simple single-phase bridgeless boost AC-DC converter with low input current distortion and high efficiency has been proposed and verified. The proposed bridgeless topology is derived from the conventional boost converter. Comparing with conventional boost PFC circuit, the converter chops the input current at the AC side in contrast to the conventional design which chops the rectified output. The comparison was the conventional boost converter using PSIM 9.1 environment. The proposed scheme demonstrated improved performance having low input current THD, high power factor, and high efficiency which complies with the IEEE standards. However, if a more precise output is desired controller design with feedback loop could be implemented.

REFERENCES

[1] H.-S. Cho, et al., "Bridgeless half-bridge AC-DC converter with series-connected two transformers," in 2013 Twenty-Eighth Annual IEEE Applied Power Electronics Conference and Exposition (APEC), 2013, pp. 3241-3245.

[2] M. Arias, et al., "High-efficiency asymmetrical half-bridge converter without electrolytic capacitor for low-output-voltage AC–DC LED drivers," IEEE transactions on Power Electronics, vol. 28, pp. 2539-2550, 2013.

[3] M. S. Arifin and M. J. Alam, "Input switched high performance single phase single switch Ćuk AC-DC converter," in 2015 International Conference on Advances in Electrical Engineering (ICAEE), 2015, pp. 226-229.

[4] M. M. S. Khan, et al., "Input switched high performance three phase Buck-Boost controlled rectifier," in 2013 IEEE International Conference on Industrial Technology (ICIT), 2013, pp. 557-562.

[5] M. R. T. Hossain, et al., "A single phase SEPIC AC-DC converter with improved power factor and input current THD," in 2016 9th International Conference on Electrical and Computer Engineering (ICECE), 2016, pp. 373-376

[6] U. Kamnarn and V. Chunkag, "Analysis and design of a modular three-phase AC-to-DC converter using CUK rectifier module with nearly unity power factor and fast dynamic response," IEEE transactions on Power Electronics, vol. 24, pp. 2000-2012, 2009.

[7] M. I. Hossain and M. J. Alam, "Cuk topology based power factor correction and output voltage regulation of AC-DC converter," in 2014 International Conference on Electrical Engineering and Information & Communication Technology, 2014, pp. 1-6.

[8] J.-H. Kim, et al., "Boost integrated flyback AC-DC converter with valley fill circuit for LED light bulb," in Proceedings of The 7th International Power Electronics and Motion Control Conference, 2012, pp. 457-462

[9] M. Mahmood, et al., "Isolated dual boost bridgeless power factor correction AC-DC converter," in 2013 1st International Future Energy Electronics Conference (IFEEC), 2013, pp. 465-470.

[10] G. Spiazzi and P. Mattavelli, "Design criteria for power factor preregulators based on SEPIC and Cuk converters in continuous conduction mode," in Proceedings of 1994 IEEE Industry Applications Society Annual Meeting, 1994, pp. 1084-1089.

[11] M. S. Arifin and M. J. Alam, "Input switched single phase SEPIC controlled rectifier with improved performances," in 2016 9th International Conference on Electrical and Computer Engineering (ICECE), 2016, pp. 38-41.

[12] N. A. Ahmed, "Modeling and simulation of ac–dc buck-boost converter fed dc motor with uniform PWM technique," Electric power systems research, vol. 73, pp. 363-372, 2005.

[13] B. Axelrod, et al., "Switched-capacitor/switched-inductor structures for getting transformerless hybrid DC–DC PWM converters," IEEE Transactions on Circuits and Systems I: Regular Papers, vol. 55, pp. 687-696, 2008.

[14] Q. Lu, et al., "DC-DC converters," ed: Google Patents, 1997.

[15] B. Singh, et al., "A review of three-phase improved power quality AC-DC converters," IEEE Transactions on Industrial Electronics, vol. 51, pp. 641-660, 2004.

[16] M. A. Kabir, et al., "Boost and Buck topology based single phase AC-DC converters with low THD and high power factor," in 2011 IEEE 33rd International Telecommunications Energy Conference (INTELEC), 2011, pp. 1-7.

[17] K. Akter, et al., "Close Loop Analysis of a Single Phase High-Efficiency AC-DC CUK Converter with Low Input Current THD and Improved Power Factor," in 2018 10th International Conference on Electrical and Computer Engineering (ICECE), 2018, pp. 393-396.

[18] K. Akter, et al., "Modeling and Simulation of Input Switched AC-DC SEPIC Converter with PFC Control for optimized Operation," in 2018 4th International Conference on Electrical Engineering and Information & Communication Technology (iCEEiCT), 2018, pp. 240-245.