Quasi Switching Buck-Boost Converter for Transmission Line

Ms.P.Aileen Sonia Dhas[1] , Ms. S.L. Sree Devi[2], Mr.R.Tamilamuthan[3], Mr.A.Antony Charles4, Ms.B.Pandyselvi[5] ,Dr.K.Deepa[6], Dr. R. Kanthimathi[7], B. Dhivya[8]
Assistant Professor, Department of Electrical and Electronics Engineering/Peri Institute of Technology, Chennai

Abstract: This paper presents the design and implementation of a quasi-switching buck-boost converter for voltage regulation in power transmission lines. The converter is designed to step up or step down the voltage of the power being transmitted along the line to maintain a stable voltage at the load end. The quasi-switching circuitry allows the switching device to turn off naturally when the current through it reaches zero, reducing switching losses and EMI, and improving overall efficiency. The paper describes the methodology for designing the converter, including selection of components, control circuitry, and testing and optimization. Simulation and experimental results demonstrate the effectiveness of the converter for voltage regulation in power transmission lines, showing stable output voltage, high efficiency, and low output ripple. The proposed converter can be a useful tool for voltage regulation in power transmission lines, helping to maintain a stable voltage at the load end and improve overall efficiency.

Keywords: quasi switching, voltage regulation, stable voltage, switching loss, low output ripple, improve overall efficiency

I INTRODUCTION

A quasi-switching buck-boost converter is a type of DC-DC converter that can be used for voltage regulation in power transmission lines. The converter steps up or steps down the voltage of the power being transmitted along the line to maintain a stable voltage at the load end.In power transmission, it is important to maintain a stable voltage at the load end of the line to prevent damage to equipment and ensure efficient power transfer. However, voltage drops and fluctuations can occur due to a variety of factors, including distance, line resistance, and varying loads. To address these issues, voltage regulation techniques are used to maintain a stable voltage at the load end. A quasi-switching buck-boost converter is one such voltage regulation technique. It uses a buck-boost topology to step up or step down the voltage of the power being transmitted along the line. The converter operates in a quasi-switching mode, which allows the switching device (such as a MOSFET) to turn off naturally when the current through it reaches zero, reducing switching losses and EMI. This improves the overall efficiency of the converter and helps to maintain a stable voltage at the load end of the transmission line.

Overall, a quasi-switching buck-boost converter is a useful tool for voltage regulation in power transmission lines, helping to maintain a stable voltage at the load end and improve overall efficiency. It can also be used in other applications, such as solar power systems, where it is used to convert DC voltage to AC voltage for use in powering AC loads.

II. OPERATION OF THE PROPOSED MQZS DC-DC STEP-UP CONVERTER

Figure 1 illustrates the structure of the existing quasi switching boost converter. The SI circuits are used to expand the voltage gain more than the traditional boost dc-dc converter. Nevertheless, the voltage strain over the MOSFET raises with the converter gain; therefore, the MOSFET voltage stress is equal to the load voltage of the QZS converter. Therefore, the suggested converter voltage gain is slightly increased by the slight modification in the connection, and the voltage stress is condensed by connecting one diode and capacitor extra than the converter. The circuit structure of the suggested MQZS boost converter is depicted, in which the inductors are discharging series and charging parallel to realize a high voltage gain.

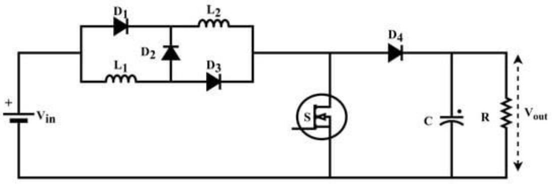

Figure 1. Existing SI-based QZS step-up converter topology.

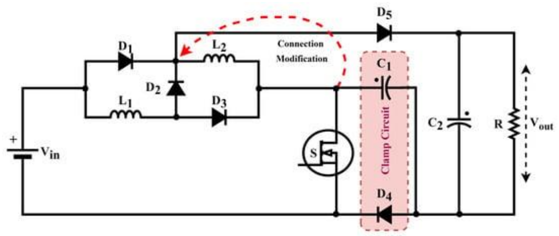

Figure 2. Suggested SI-based quasi switching buck boost converter structure.

As indicated, the converter is different from the traditional QZS converter in two ways. Firstly, the connection of the output diode, D_5, is changed to the junction point of the diode, D_1, D_2, and L_2 (as indicated with red color arrow mark), which improves the voltage gain. Secondly, the clamping network that contains one capacitor, C_1, and one diode, D_4, is added (as indicated in the pink color box line), reducing the stress on the MOSFET switch. The following hypotheses are formulated before beginning the circuit analysis.

- The selected power semiconductors are ideal
- The proposed converter is working in the mode of continuous conduction
- Pulse-width modulation is the control approach utilized by switch *S*

The converter operation is divided into two modes. The theoretical waveform is illustrated in. The current path during the two modes is illustrated

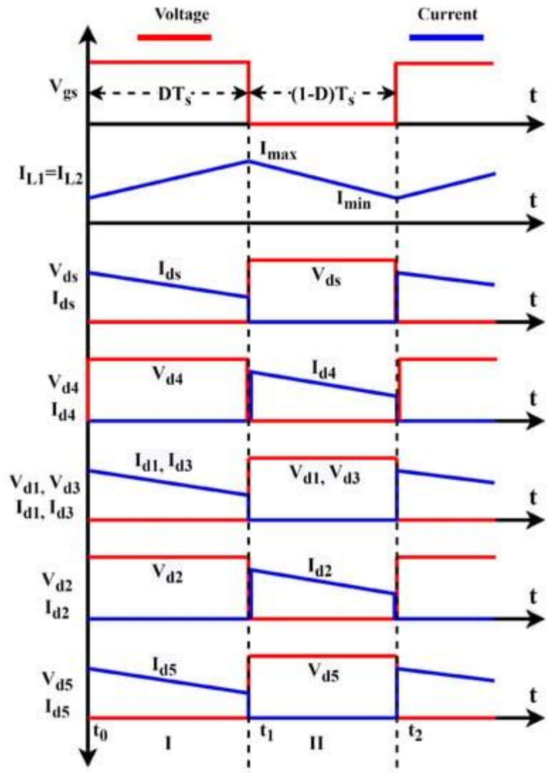

Figure 3. Theoretical waveforms of the MQZS step-up converter.

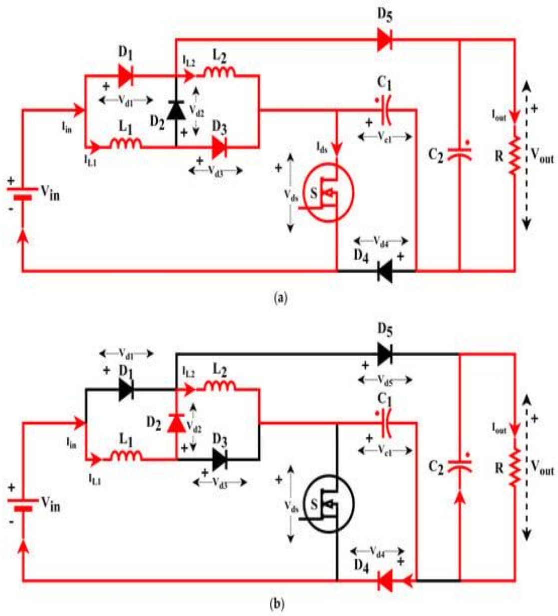

Figure 4. Operating modes of the MQZS; (a) Mode−a; (b) Mode−b.

Mode-a ($t_0 - t_1$): Mode-a starts when the MOSFET device, *S*, is turn-on. The current path is illustrated. During this mode, the inductors, L_1 and L_2, charge over the diodes, D_3 and D_1. The diode, D_5, is forward biased due to its higher potential and distributes the required energy to the load. In addition, the C_1 is getting charged through the load and the diode, D_5. The diodes D_2 and D_4 are reverse-biased due to their lower potentials. The mode ends when *S* is switched off at $t = t_1$. Throughout this duration, the output capacitor, C_2, stores the energy.

Mode-b ($t_1 - t_2$): When the *S* is switched off, mode-b starts at $t = t_1$. The current path is illustrated . The diodes D_1, D_3, and D_5 are turned off due to their lower potential, and the diodes D_4 and D_2 are forward biased due to their higher potential points. During this mode, both the inductors start discharging the energy through the diode D_2, the diode D_4 and the clamp capacitor C_1. Thus, the MOSFET voltage stress is condensed by the C_1 and the diode, D_4. The output capacitor delivers the energy required by the load during mode-b. When the switch, *S*, is switched on, this mode is terminated at $t = t_2$.

III SIMULATION RESULTS

The electrical specification and various variables of the proposed MQZS converter are recorded. The simulation was performed using PLECS standalone software installed in a laptop with a 4.44 GHz clock frequency and 16 GB RAM. The same has been included in the revised version. The performance of the MQZS converter is validated using the specifications.

As discussed earlier, the converter is simulated with the input voltage at 30 V and a constant load at 100 Ω (400 W). The MOSFET duty cycle is adjusted to 70% to reach the required voltage gain of 6.67. First, the simulation waveforms for the V_{ds} and Vd4, and the current stress of S and D_4 are demonstrated in Figure 5.

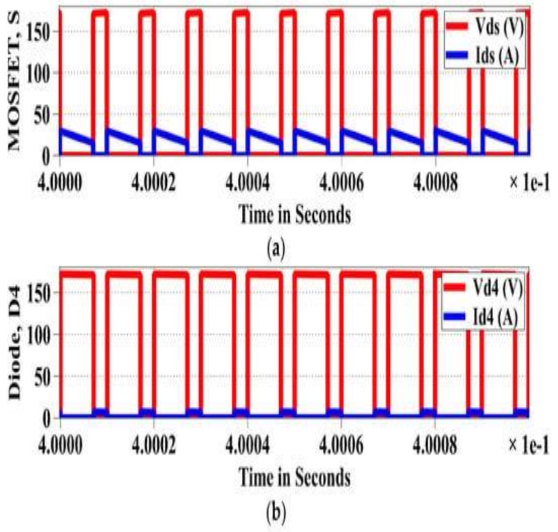

Figure 5. Current and voltage stress waveforms: (a) MOSFET switch, S; (b) Diode, D_4.

From the figure5, MOSFET switch voltage stress and D_4 are noticed as 170 V and are equal to the theoretical discussion as per Equation (8). To prove the converter operation in CCM, the current wave shape of inductors is seen in It is seen from that the converter is operating at CCM (current never reaches zero at any instant). The inductor's average current is equivalent to 6.95 A.

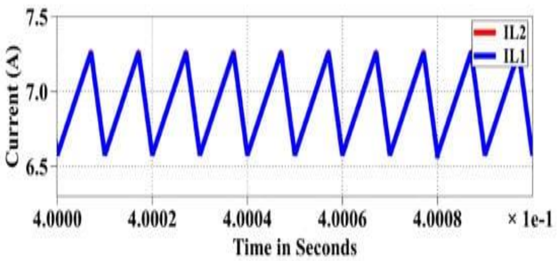

Figure 6. Inductor current waveforms of the converter.

The current and voltage stresses of the diodes, D_1–D_3 and D_5 are demonstrate. From,b, the diode voltage stress, 3 are equivalent to 70 V. The diode voltages, , are equal to 30 V, as realized The voltage across the diode, , is equal to 100 V, as realized. All the voltages are equal to the theoretical values as per Equations

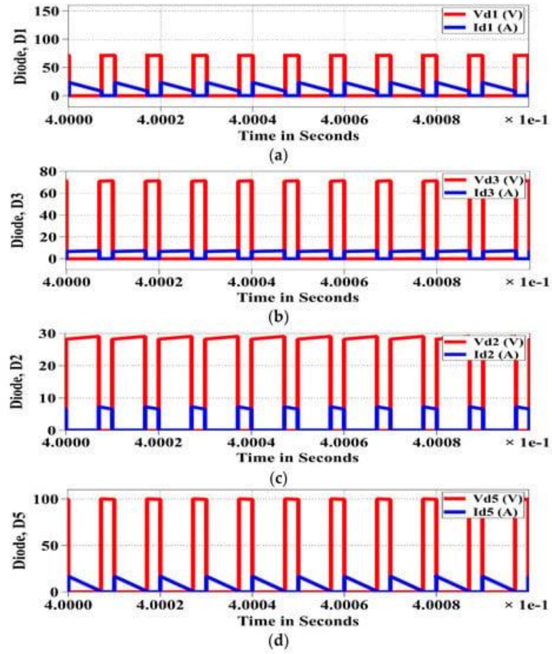

Figure 7. Current and voltage stress waveform: (a) Diode, D_1; (b) Diode, D_3; (c) Diode, D_2; (d) Diode, D_5.

Figure 8 depicts the waveforms for the capacitor, the source voltage, and the input current. Fro, it is noticed that the capacitor voltage is equal to 170 V as per Equation The main benefit of the MQZS step-up converter is a continuous input current. The input current is continuous, as seen in figure.

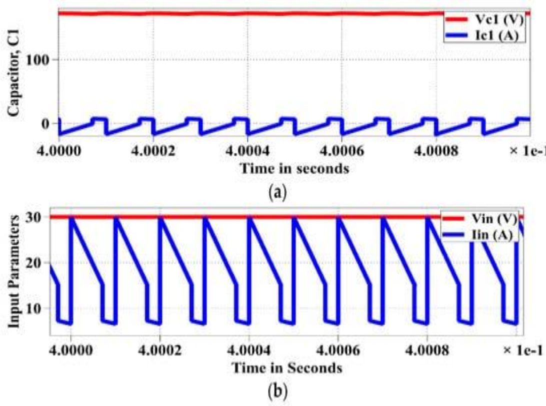

Figure 8. Current and voltage stress waveforms: (a) Capacitor, C_1; (b) Input source.

Figure 9 illustrates the output voltage and current waveforms of the MQZS converter. It is noticed from Figure 9a that the load voltage is equal to 200 V with the output current of 2 A, as seen

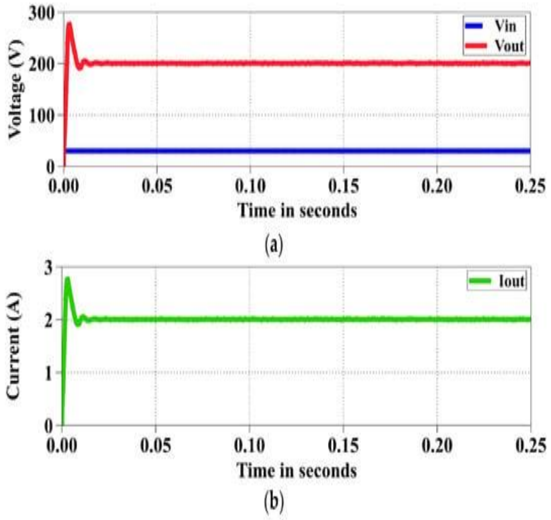

Figure 9. Current and voltage waveforms: (a) Output voltage; (b) Output current.

From the above simulation results, the MQZS converter performs better according to theoretical analysis, as noted. In addition, the proposed MQZS DC-DC converter accomplishes better performance than the traditional QZS converter.

5. Hardware Results

The experimental prototype of the suggested MQZS converter with a 400 W rating is made and verified in the research laboratory environment. The electrical specification of the MQZS converter is recorded, and the devices required for the prototype are recorded.

The duty cycle of the MOSFET device is tuned to 70% to obtain the essential voltage gain from the proposed converter. The MQZS converter's current and voltage waveforms are seen in or V_{in} = 30 V and V_{out} = 200 V. The switching frequency of the MOSFET switch is 100 kHz. The source voltage and input current waveform are illustrated in Fia. As seen in average input current is A. It is also noted that the source current is continuous. The voltage across L_1 and L_2 is depicted in . The average current of both L_1 and L_2 is equal to 7.08 A, and the CCM operation of the converter was also observed. In addition, the output voltage and output current of the MQZS converter is depicted.

As seen , the output current of the MQZS converter is equal to 2.1 A, and the output voltage of the converter is equivalent to 198.2 V

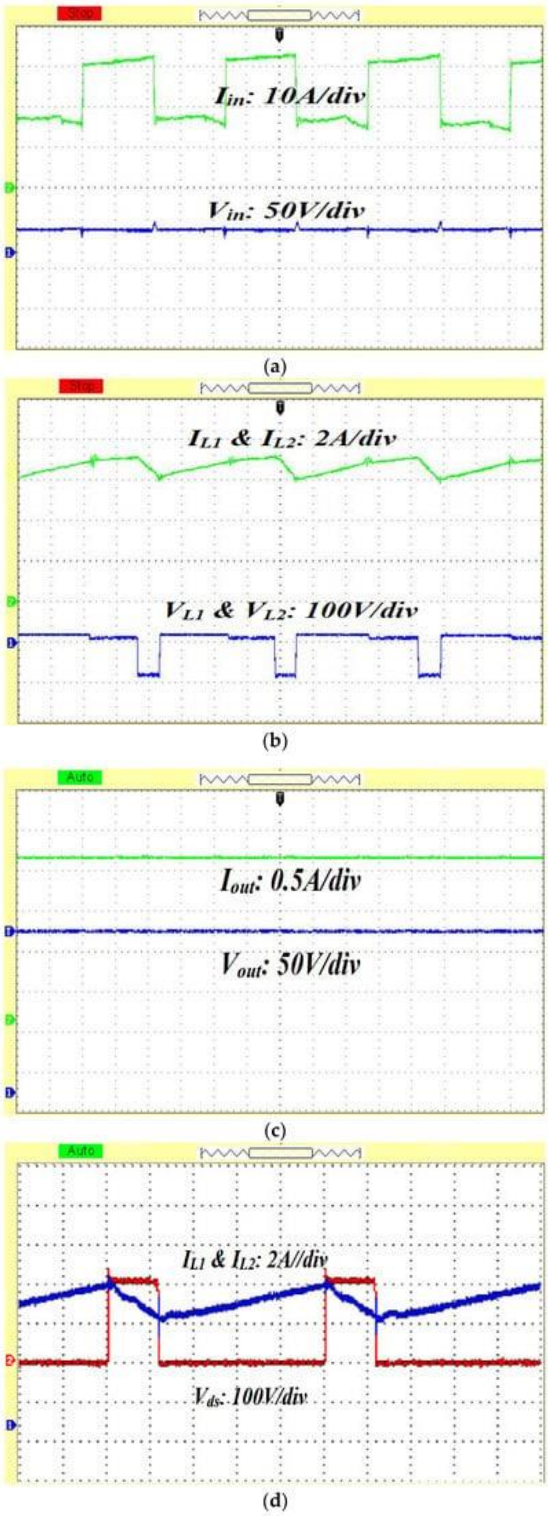

Figure 10. Experimental waveforms of the MQZS converter.

The MOSFET switch voltage stress is less than 200 V as per Equation (8), and it has been seen . In addition, the continuous conduction mode of the converter is confirmed, as seen The various voltage waveforms are shown in figure 11.

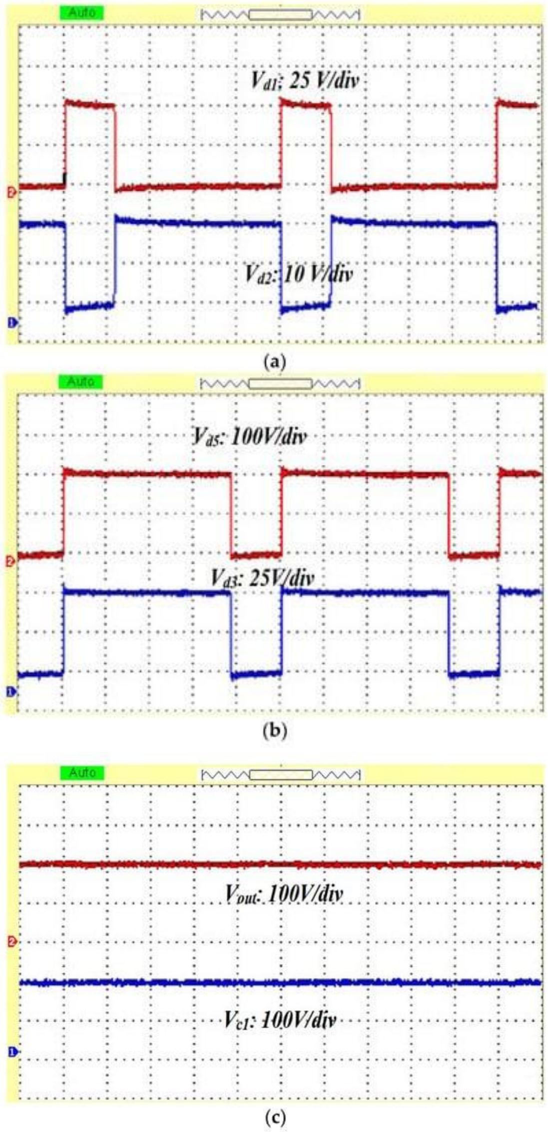

Figure 11. Various waveforms:

As seen, the voltage of the diode D_1 is less than 70 V, and the voltage across the diode D_2 is less than 30 V, and these voltages are the same as per Equation and Equation displays the voltage waveforms of Vd33 and Vd55, and the values of these voltages are equal to 58 and 200 V, respectively, as per Equation and Equation (). The capacitor voltage, Vc11, waveform is illustrated and equals less than 170 V.

The proportional-integral (PI) controller verifies the dynamic response of the MQZS converter. The output voltage of the converter is sensed using the voltage sensor, LEM LV 25-P, and fed to the comparator to compare the actual voltage and converter's reference voltage. The controller gain of the PI controller is chosen as $K_i = 0.01$ and $K_p = 0.5$ based on the trial-and-error method. The voltage control can control the output voltage at 200 V, even if the input voltage is continuously changed, as shown from 35 to 25 V. The source voltage is retained as 30 V at the beginning, and at t = 5 s, the source voltage is changed to 35 V and changed to 25 V in 10 s again. The proposed converter's dynamic output voltage waveform for the change in input voltage is seen As seen , the MQZS converter maintains a constant output voltage, regardless of the input voltage change.

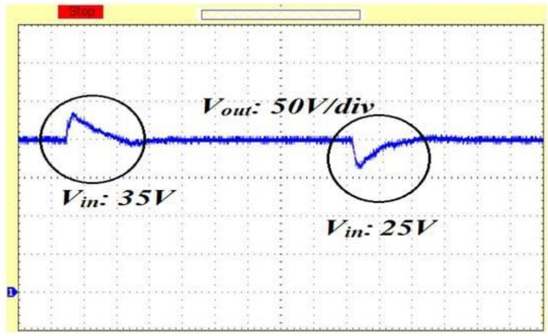

Figure 12. Dynamic response of the MQZS converter.

The switch voltage stress and capacitor voltage stress of the proposed converter are lesser than the traditional QZS converter for the same output voltage. The traditional converter can obtain the output voltage of 109.09 V at 57% of the duty cycle, whereas the proposed converter can obtain the same output voltage at 45% of the duty cycle. From these discussions, it is concluded that the performance of the proposed converter better than the traditional QZS converter in all aspects. Thus, the dimensions and cost of the suggested MQZS converter have been reduced mostly. displays the voltage gain characteristics of the MQZS converter and other similar converters in the literature. Besides, the MQZS converter voltage gain by considering the internal elements of various components is also demonstrated

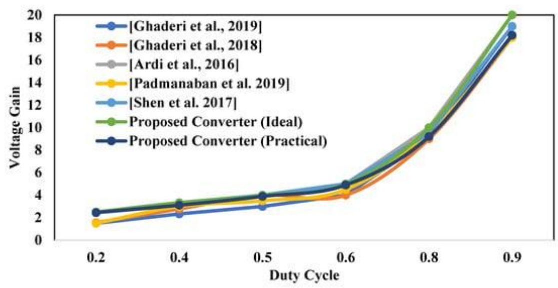

Figure 13. Voltage gain characteristics of various converters

Figure 13. shows that the voltage gain is reduced at a high duty cycle due to the influence of parasitic

components of various devices. Therefore, it is not advisable to operate the converter at a high duty cycle, i.e., beyond 70% duty cycle. In addition, the high duty cycle also reduces the conversion efficiency due to high voltage drop across the parasitic elements and the conduction power losses. The efficiency curve assessment of the suggested MQZS converter with the other converter structures is illustraAs seen, the effectiveness of the suggested MQZS converter is high due to a smaller number of components when related to the converters discussed in the literature. The maximum efficiency of the MQZS converter at 300 W is 94.2%, and the converter's efficiency at full load is equivalent to 93.1%.

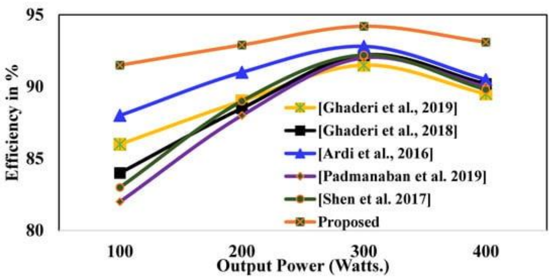

Figure 14. Efficiency curve of different converters

6. CONCLUSIONS

In this paper, traditional QZS converter and modified the QZS dc-dc boost converter with one MOSFET switch is comprehensively studied and analyzed. The proposed MQZS converter is an enhanced version of the traditional QZS converter, as it offers a high voltage gain, similar to the QZS converter. The prototype of the proposed MQZS dc-dc converter is made and experimented with in the laboratory environment. The experimental outcomes confirm the theoretical discussion and simulation results of the MQZS dc-dc converter. The operation, analysis, and parameter selection of the proposed MQZS converter were detailed in this paper. Moreover, the performance comparison is made with converters in previous works, and it is noted that the proposed MQZS converters offer high performance in the non-isolated converter category. The MQZS dc-dc converter can attain high output voltage gain with less voltage switch stress of the MOSFET, diodes, and capacitor. It also has benefits such as low cost and high-power density. Thus, the suggested MQZS converter is more appropriate for renewable energy systems that require a high output voltage from a low source voltage. In the future, the proposed converter can also be extended to various applications, such as electric vehicle power train systems, solar photovoltaic powered pumping systems, DC microgrid systems, etc.

REFERENCE

[1] Wu, G.; Ruan, X.; Ye, Z. Non-isolated high step-up DC-DC converter adopting auxiliary capacitor and coupled inductor. *J. Mod. Power Syst. Clean Energy* 2018, *6*, 384–398.

[2] Premkumar, M.; Kumar, C.; Sowmya, R. Analysis and implementation of high-performance DC-DC step-up converter for multilevel boost structure. *Front. Energy Res.* 2019, *7*, 149.

[3] Leon-Masich, A.; Valderrama-Blavi, H.; Bosque-Moncusí, J.; Martínez-Salamero, L. A High-Voltage SiC-Based Boost PFC for LED Applications. *IEEE Trans. Power Electron.* 2016, *31*, 1633–1642.

[4] Premkumar, M.; Kumar, C.; Anbarasan, A.; Sowmya, R. A novel non-isolated high step-up DC-DC boost converter using single switch for renewable energy systems. *Electr. Eng.* 2020, *102*, 811–829.

[5] Premkumar, M.; Sowmya, R.; Karthick, K. A dataset of the study on design parameters for the solar photovoltaic charge controller. *Data Brief* 2018, *21*, 1954–1962.

[6] Premkumar, M.; Sumithira, T.R. Design and implementation of new topology for solar PV based transformerless forward microinverter.*J. Electr. Eng. Technol.* 2019, *14*, 145–155.

[7] Forouzesh, M.; Siwakoti, Y.; Gorji, S.; Blaabjerg, F.; Lehman, B. Step-Up DC-DC Converters: A Comprehensive Review of Voltage-Boosting Techniques, Topologies, and Applications. *IEEE Trans. Power Electron.* 2017, *32*, 9143–9178.

[8] Richard, C.; McDonald, K.; St-Onge, X.; Saleh, S. A New Isolated DC-DC Converter for Discontinuous Input and Continuous Output. *IEEE Trans. Ind. Appl.* 2019, *55*, 4215–4224.

[9] Park, K.; Moon, G.; Youn, M. Non-isolated High Step-up Boost Converter Integrated with Sepic Converter. *IEEE Trans. Power Electron.* 2010, *25*, 2266–2275.

[10] Dwari, S.; Parsa, L. An Efficient High-Step-Up Interleaved DC-DC Converter with a Common Active Clamp. *IEEE Trans. Power Electron.* 2011, *26*, 66–78.

[11] Liu, H.; Li, F. Novel High Step-Up DC-DC Converter with an Active Coupled-Inductor Network for a Sustainable Energy System. *IEEE Trans. Power Electron.* 2015, *30*, 6476–6482.

[12] Dhananjaya, M.; Potnuru, D.; Manoharan, P.; Alhelou, H.H. Design and Implementation of Single-Input-Multi-Output DC-DC Converter Topology for Auxiliary Power Modules of Electric Vehicle. *IEEE Access* 2022, *10*, 76975–76989.

[13] Tang, Y.; Wang, T.; Fu, D. Multicell Switched-Inductor/Switched-Capacitor Combined Active-Network Converters. *IEEE Trans. Power Electron.* 2015, *30*, 2063–2072.

[14] Prabhala, V.; Fajri, P.; Gouribhatla, V.; Baddipadiga, B.; Ferdowsi, M. A DC-DC Converter with High Voltage Gain and Two Input Boost Stages. *IEEE Trans. Power Electron.* 2016, *31*, 4206–4215

[15] Premkumar, M.; Sumithira, T.R. Design and implementation of new topology for non-isolated DC-DC microconverter with effective clamping circuit. *J. Circuits Syst. Comput.* 2019, *28*, 1950082.

[16] Abdel-Rahim, O.; Orabi, M.; Abdelkarim, E.; Ahmed, M.; Youssef, M.Z. Switched inductor boost converter for PV applications. In Proceedings of the Twenty-Seventh Annual IEEE Applied Power Electronics Conference and Exposition, Orlando, FL, USA, 5–9 February 2012; pp. 2100–2106. [Google Scholar]

[17] Tang, Y.; Xie, S.J.; Zhang, G.H.; Xu, Z.G. Improved Z-source inverter with reduced Z-source capacitor voltage stress and soft-start capability. *IEEE Trans. Power Electron.* 2009, *24*, 409–415.

[18] Ghaderi, D.; Bayrak, G. Performance Assessment of a High-Powered Boost Converter for Photovoltaic Residential Implementations. *Elektron. Elektrotech.* 2019, *25*, 40–47.

[19] Ghaderi, D.; Çelebi, M.; Minaz, M.R.; Tören, M. Efficiency improvement for a DC-DC quadratic power boost converter by applying a switch turn-off lossless snubber structure based on zero voltage switching. *Elektron. Elektrotech.* 2018, *24*, 15–22.

[20] Ardi, H.; Ajami, A.; Kardan, F.; Avilagh, S.N. Analysis and implementation of a nonisolated bidirectional DC-DC converter with high voltage gain. *IEEE Trans. Ind. Electron.* 2016, *63*, 4878–4888.

[21] Piresa, V.F.; Foitoa, D.; Silvab, J.F. A single switch hybrid DC/DC converter with extended static gain for photovoltaic applications. *Elect. Power Syst. Res.* 2017, *146*, 228–235.

[22] Marzang, V.; Hosseini, S.H.; Rostami, N.; Alavi, P.; Mohseni, P.; Hashemzadeh, S.M. A high step-up non-isolated dc-dc converter with flexible voltage gain. *IEEE Trans. Power Electron.* 2020, *35*, 10489–10500.

[23] Lee, S.; Do, H. Quadratic boost DC-DC converter with high voltage gain and reduced voltage stresses. *IEEE Trans. Power Electron.* 2018, *34*, 2397–2404.

[24] Maroti, P.K.; Al-Ammari, R.; Bhaskar, M.S.; Meraj, M.; Iqbal, A.; Padmanaban, S.; Rhaman, S. New tri-switching state non-isolated high gain DC-DC boost converter for microgrid application. *IET Power Electron.* 2019, *12*, 2741–2750.

[25] Padmanaban, S.; Maroti, P.K.; Holm-Nielsen, J.B.; Blaabjerg, F.; Leonowicz, Z.; Yaramasu, V. Quazi Z-Source Single Stage High Step-Up DC-DC Converter for Grid-connected PV Application. In Proceedings of the International Conference on Environment and Electrical Engineering and IEEE Industrial and Commercial Power Systems Europe, Genova, Italy, 10–14 June 2019; pp. 1–6. [Google Scholar]