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Performance Analysis and Simulation of a High-Gain DC–DC Quadratic Boost Converter for Renewable Energy Integration

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***Abstract*—This paper presents DC power supply can be generated by rectifier, while the input is ac. In rectifiers output has more ripples and also no capability to step up the output in itself. DC- DC boost converters are the important and most useful power electronic circuitries in which the electrical dc voltage can be step-up to a certain level of dc voltage. The DC-DC cascade boost converters have high step-up boosting capability. Quadratic converters are robust and compact in size, boosting of dc voltage level and losses can be optimised by implementing the optimal switching techniques. In proposed model a single switch Quadratic DC-DC boost converter is proposed to solve the high step-up output voltage requirement problem. This is the converter of quadratic category gives largest voltage boosting factor and high efficiency as compare to any other boost converter. Working with the single switch, this converter overcomes the problem of switching losses and improves efficiency as compared to cascaded two single stage quadratic boost converters. The switching losses and switch stress can be optimised by optimal switching. The modulating signal as an output of the comparator is the difference of reference signal and output voltage, passing through PID Controller and further compared logically to generate proper sequence of pulse train. The validity and functionality of the proposed model is verified by the simulation in MATLAB/Simulink. The results show that the proposed boost converter significantly improves & perform well as compared to existing state of the art boost converters topologies**.

Keywords*—*high gain, DC–DC boost, renewable energy, photovoltaic, coupled inductor, switched-capacitor, quasi-Z-source, wide-bandgapResonant Frequency, Return Loss (S11), Bandwidth, Gain, Radiation Pattern.

I. INTRODUCTION

The A High-Gain Quadratic Boost Converter (QBC) is an advanced DC–DC converter topology designed to achieve a significantly higher voltage gain compared to conventional boost converters, making it highly suitable for renewable energy integration. In renewable energy systems such as solar photovoltaic (PV), fuel cells, or wind energy applications, the generated voltage is often low and fluctuating, requiring efficient voltage boosting to meet the required load or grid interface levels. The QBC employs multiple energy storage elements and quadratic voltage conversion stages to attain a large voltage step-up ratio while maintaining moderate duty cycles, improved efficiency, and reduced component stress. Its design minimizes power losses and enhances dynamic response, thereby ensuring stable operation under varying input conditions typical of renewable sources. Due to these advantages, the High-Gain Quadratic Boost Converter is widely explored for integrating low-voltage renewable sources into high-voltage DC or AC systems, promoting reliable and efficient renewable energy utilization.

A. Micro-Grid

A microgrid usually includes various micro sources and loads, which operate as an independent and controllable system when they are either grid-connected or isolated. The micro source is classified as DC source or as a high-frequency AC source. These two micro source categories comprise of diverse renewable energy applications such as wind power sources, photovoltaic cells, fuel cells, and reciprocating engines. Fig. 1 shows a block diagram of microgrid unit being supplied by different micro sources. Step-up converter is used to increase the output voltage of the micro source to a desired voltage level given to dc-ac inverter. The fuel cells stack or single solar cell module both are essentially low-voltage sources and thus a high step-up voltage gain DC-DC converter is required to regulate the voltage of the DC interface. The range of electric vehicles requires fast charging stations that enable to recharge a vehicle battery in a few minutes.

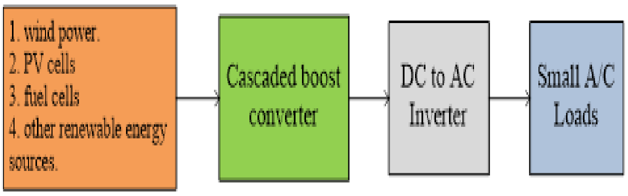

Fig. 1 Block Diagram of Microgrid

B. DC-DC Regulators

In many industrial applications, it is required to convert a fixed-voltage dc source into a variable- voltage dc source. A dc chopper converts directly from dc-to-dc voltage and is also known as a dc-to-dc converter. A chopper can be considered as dc voltage booster equivalent to an ac transformer with a continuously variable turn's ratio. Like a transformer, it can be used to step-down or step- up a dc voltage source. Choppers are mostly used for traction motor control in electric automobiles. They provide smooth acceleration control, fast dynamic response and high efficiency. Choppers can be used in regenerative braking [10], of dc motors and this feature results in energy savings for transportation systems with frequent braking. Choppers are used in dc voltage regulators and also used, in conjunction with an inductor, to generate a dc current source, especially for the current source inverter

II. LITRATURE REVIEW

Hamed Farag Elghabsi et al. (2025) - The suggested high VGN, high-efficiency QBC presented in this study, a new method for applying renewable energy is presented. By employing a coupled inductor and an active clamp network, this converter provides VGN without requiring extreme D, addressing the Limitations of traditional converters. Notably, the design facilitates ZVS for the energy switches and ZCS for the diodes, minimizing switching losses and remarkably enhancing efficiency. This soft-switching operation, combined with low VSS through semiconductor devices, ensures improved reliability and longevity for the system. Furthermore, a continuous input and output current waveform and the common ground connection between input and output simplify integration with other system components in renewable energy systems. Through a 250 W hardware prototype, experimental results validate the converter's capability to deliver elevated voltage earning and efficiency under load conditions, outperforming comparable designs in the literature. The converter's efficiency, with peak values reaching 97%, demonstrates the prospect of this design to enhance the performance and cost-effectiveness of renewable energy applications. This QBC topology, with its enhanced power density and soft-switching capability, sets a new benchmark for high-performance, non-isolated converters in solar power technology [01].

Ali Nadermohammadi et al. (2025) - DC microgrids play a pivotal role in smart grid systems, improving grid reliability, power quality, and energy efficiency 1720 VOLUME 6, 2025 while allowing for autonomous operation. By integrating distributed and renewable energy sources, these systems help to lower the entire energy demand. High-gain DC–DC topologies are essential for stepping up voltages from low-voltage DC resources like solar panels and wind turbines, making them invaluable for DC microgrids. This paper presents a quadratic ultra-high step-up topology with minimal input current ripple tailored for DC microgrid applications. The propounded structure has been compared with 18 other topologies from 2023 and 2024, with seven of these labeled as ultra-high step-up types [02].

Chang-Hua Lin et al. (2024) -High-gain DC-DC converters are becoming increasingly popular in renewable energy applications and solar PV systems. The converter comprises only two switches, and a single PWM signal governs its operation. These characteristics result in a topology that is more compact, less costly, lighter weight, and easier to control. The proposed converter is compared with some previously developed topologies of high-gain boost converters across various performance parameters. This comparison illustrates that the proposed model surpasses them in every aspect. A 300 W hardware prototype of a proposed model is developed and tested in a laboratory environment to confirm the theoretical assertions of a proposed model. The proposed topology offers a promising solution and enables a high gain of approximately 12 times the input voltage at a smaller duty ratio, specifically 11.25 at a duty of 0.6 and 17.77 at a duty of 0.7. The efficiency of a proposed converter ranges between 92.5% to 94.5% making it appropriate for numerous medium-high power applications. The uniqueness of the suggested system is its simple design and greater efficiency, which provides a more considerable gain and higher output voltages for sustainable energy systems [03].

Khaja Shahini Begum et al. (2024) - The various topologies of DC-DC boost converters which are designed for optimal integration with RES like photovoltaic (PV) systems. Photovoltaic applications demand efficient energy harvesting and management to maximize the conversion of solar energy into electrical power. The DC-DC topologies include switched coupled inductor, basic coupled inductor, coupled capacitor with coupled inductor with a snubber circuit, active clamp, high step-up and three-winding dual switches are considered for study. Each topology is analyzed in terms of its suitability for PV applications, considering factors such as efficiency, voltage gain, and reliability. The basic coupled inductor topology is explored as a reference point, providing a foundation for understanding the subsequent advanced configurations. This work explores and compares several prominent boost converter configurations, incorporating advanced techniques to enhance overall performance and efficiency for RES applications [04].

H. Shayeghi et al. (2024) - A non-isolated coupled inductor and VMC based topology. The performance and superiority of the proposed topology is verified by operation modes survey, steady-state analysis, efficiency measurement, and comparison study with other similar converters. Considering the presented analysis, the benefits of this converter can be categorized as: A) only one power switch is used in its structure, which reduces the converter's cost, B) low number of components, B) high efficiency due to the ZCS and ZVS of diodes, 4) low blocking voltage of power switch and diodes, 5) using a low rated power switch; because the VMC acts as a passive clamp circuit and reduces the voltage stress across the power switch, 6) negligible reverse recovery problem of diodes due to the ZCS. The main contribution of the proposed converter and the critical factors of the proposed converters and other converters were discussed in detail in the literature. In order to verify the mathematical analysis, a 160 W experimental prototype with 50 kHz switching frequency and 17 V input voltage are built. It was shown that the suggested structure's efficiency is higher than 95 %. Therefore, related to technical survey, steady-state calculation and the experimental result, the recommended high step-up converter could be a proper topology for renewable energy systems [05].

Arafa S. Mansour et al. (2023) -High-gain DC/DC converters are considered one of the most important components of green energy systems. Large numbers of these converters are used for increasing the voltage gain by using an extreme duty cycle. However, it increases losses and the cost, degrades the system performance, and hence obtains a low efficiency. In this article, a new design of a high-gain DC/DC boost converter is proposed. This converter has the potential to be used in low input voltage applications that need a high voltage gain such as systems powered by solar photovoltaic panels and fuel cells. The new topology is characterized by its simplicity of operation, high voltage gain, better efficiency, continuity of the input current, reduced number of inductors and capacitors, and can be extended to get higher gains. The converter structure, principle of operation, and design consideration of inductors and capacitors are presented in detail. Derivation of power losses and efficiency is presented. A laboratory prototype is implemented, and various experimental tests are given [06].

J. Gnanavadivel et al. (2023) - An efficient DC-DC converter for renewable energy applications. The proposed high-gain converter is designed with switched inductor cell and voltage multiplier cell. In the proposed converter, the continuous source current is obtained by switched inductor cells, and high-voltage gain is achieved using voltage multiplier cells. The proposed converter provides a voltage gain of 10 when operated with a duty ratio of 27.3%, whereas a voltage gain of 39 is obtained for an 80% duty ratio. The efficiency of 96.54% is achieved in simulation for the rated condition of 24 V/240 V, 120W. The converter operation under steady-state, state-space modelling, and voltage and current stress of the power semiconductor components are analyzed. In addition to that, loss distribution and efficiency analysis are made. The performance of the converter is analyzed using the Matlab Simulink tool. Also, the experimental hardware prototype model is developed to validate the simulated and theoretical analysis [07].

Arafa S. Mansour et al. (2022) - A new non-isolated high voltage gain DC/DC converter by integrating a dual boost converter with a switched inductor structure is proposed. The proposed converter operates with a modest duty cycle (less than 0.5) with a continuous input current. The converter operates with a soft switching (ZCS) for all diodes and switches which plays an important role in reducing the losses. A wide operating range of the duty cycle is available. An equal current sharing among boost inductors makes it easy to control. Also, the proposed converter offers high efficiency due to the low switching losses, lower voltage stress for all passive and active components, and the lack of reverse recovery loss on diodes. It requires a small inductor, and a small nominal rating for all semiconductor devices which reduces the size, weight, and price of the proposed converter. These features make the converter a good choice for many applications such as PV, x-ray, fuel cells, etc. Moreover, the description, operating modes in DCM, design guidelines, and open and closed-loop performance are presented. Besides, a comparative analysis with recent converters is presented. The converter is examined at various power ratings for efficiency analysis and maximum efficiency of 93% is achieved [08].

III.METHODOLOGY

The methodology used is described that covered the procedures as well as equipment and software to be used in the entire work process. It performs the difficult task to select the suitable parameters for close loop operation as non-linearity of system involved.

A. Project Design

The proposed general block diagram for this project is shown in Fig 2and Fig 3shows the overview of the proposed flow chart of this project-

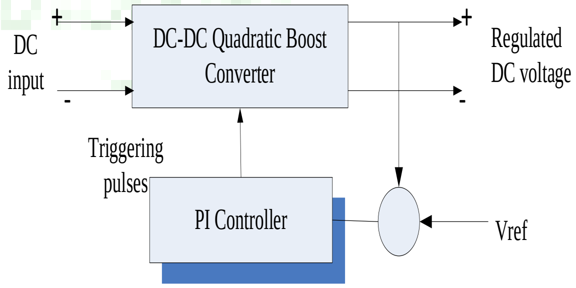

Fig 2 Proposed Model Block Diagram Using PID Controller

Controller [20], design for any system needs knowledge about system behaviour in time domain and frequency domain. Usually this involves a mathematical description of the relation among state variables, input to the process and output. This description in the form of mathematical equations which describe behaviour of the process (system) is called model [21], of the system. This thesis describes an efficient method to learn, analyse and simulation of power electronic converters, using non-linear system solution method, and switched state-space models.

B. Simulink Model Construction of DC-DC Switching Converter

System modelling is mainly the most important phase in any form of system control design work. The choice of a circuit model and its parameters depend upon the objectives of the simulation. If the performance is to predict the behaviour of a circuit before it is built. A good system model provides a designer with valuable information about the system dynamics. Due to the difficulty involved in solving general nonlinear differential equations, all the governing equations will be put together in block diagram form and then simulated using Matlab's Simulink program. Simulink will solve these nonlinear equations numerically methods like newton-rapson, and provide a simulated response of the system dynamics.

C. Model Flow Chart

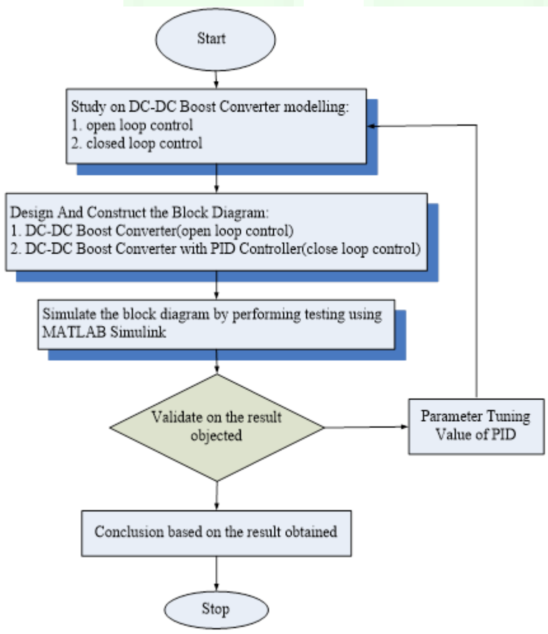

Fig 3 Flow Chart of Project Simulation

The steps to obtain a system-level modelling and simulation of power electronic converters are listed below.

- Study of Open loop and close loop control of DC-DC converter is carried out as mentioned in chapter 4.
- Then in chapter 5, Mathematical equations are utilized to design and construct block diagram for open loop as well as close loop DC-DC Converter.
- Block Diagram is then simulated on MATLAB.
- Simulated Results obtained were verified with the desired outcome. If the results are not favourable then the value of PID Controller parameters are tuned again using ZN Method and the process repeats until desired output is obtained.
- When the results are favourable the process of tuning PID Controller stops and Conclusions are being drawn on the basis of result obtained.

The proposed converter is transformer less dc-dc converter can be used for microgrid applications. The renewable energy sources such as PV modules, fuel cells or energy storage devices such as super capacitors or batteries deliver output voltage at the range of around 12 to 70 V dc. In order to connect them to the grid the voltage level should be adjusted according to the electrical network standards in the countries.

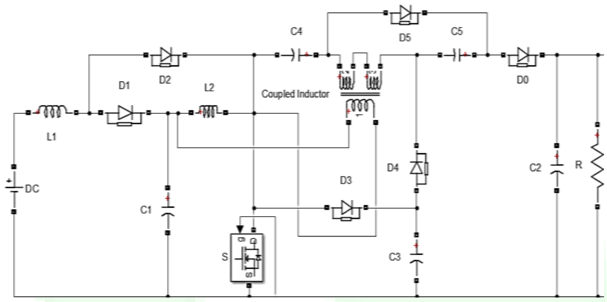

Fig 4 DC-DC Quadratic Boost Converter with Single Switch

It's a new modelling technique of a cascade Boost converter. The adaptive control is applied and gives good performances in grid side and in dc side. PID controller eliminates efficacy the steady state error of the dc bus voltages. The configuration proposed may be used to fast charging electrical vehicle battery by controlling the time charging. The configuration connected to the grid compensates current harmonics, reactive power; the THD of the grid current is less than 5%. The boost converter provides high currents, while the cascade boost converter achieves high voltage. The advantage of the high voltage of the cascade boost converter makes it very suitable for high battery voltage charging current

D. Modelling Procedure

To obtain a nonlinear model for power electronic circuits, one needs to apply Kirchhoff's circuit laws. To avoid the use of complex mathematics, the electrical and semiconductor devices must be represented as ideal components (zero ON voltages, zero OFF currents, zero switching times). Therefore, auxiliary binary variables can be used to determine the state of the switches. It must be ensured that the equations obtained by the use of Kirchhoff's laws should include all the permissible states due to power semiconductor devices being ON or OFF

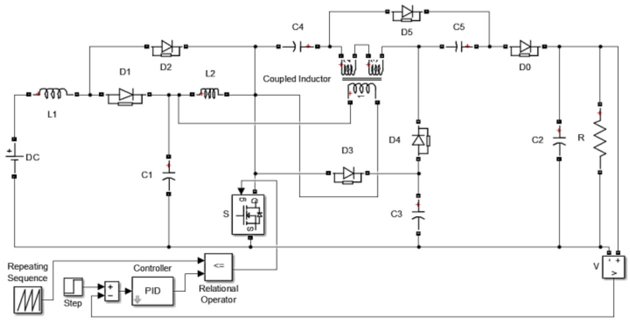

Fig 5 DC-DC Quadratic Boost Converter with closed loop control

IV. RESULT AND ANALYSIS

A. Simulation Result

On the basis of methodology and mathematical modelling proposed in earlier discussions, the values of various circuit parameters were calculated and are tabulated as below.

B. Design Parameters

The model parameters are shown Table I, with which the experimentation is performed. These are the parameters which have been calculated and for designing of the converter circuit.

Table 1 Open Loop & Close Loop Boost converter design parameters

Type of Boost Converter	V_{in} (v)	L_1 (µH)	L_2 (µH)	C_1 (µF)	C_2 (µF)	F (KHz)	R (Ω)	L_M (µH)
Open Loop Converter	30	10	8	12	200	50	25	250
Close Loop Converter	30	200	20	10	50	1	10	250

C. Open Loop Converter

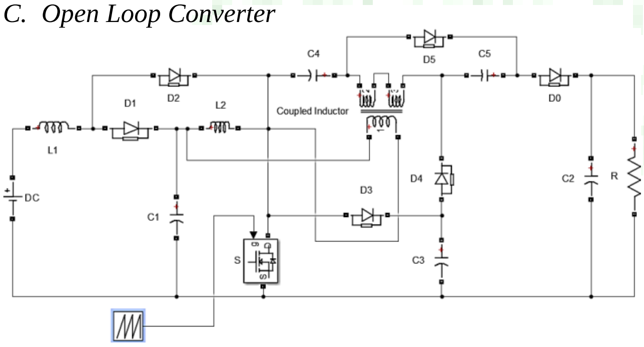

Fig 6 Circuit Diagram of Open Loop Converter

The high step dc-dc quadratic converter having single switch and the coupled inductor to improve the boosting of the output voltage. When the open loop cascade converter is operated, the diode voltage, current exist which is shown in scope 1 of Figure 7 Diode current flows as the preceding circuit response.

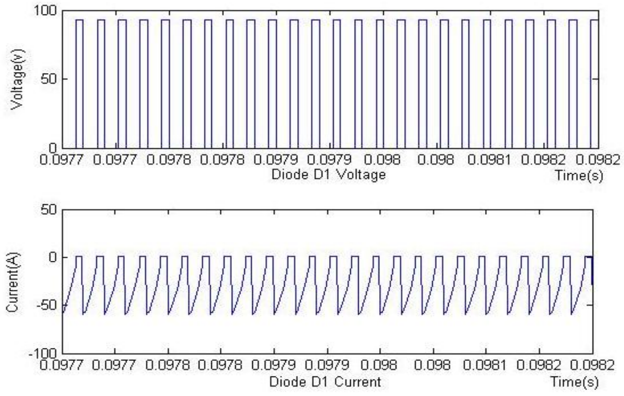

Fig 7 Diode D1 current and voltage

The output current of proposed cascaded dc-dc boost converter is shown in scope 2 of Figure 8 Maximum current is about 25 amperes while minimum current is 2 amperes. The average current is nearly 10 amperes.

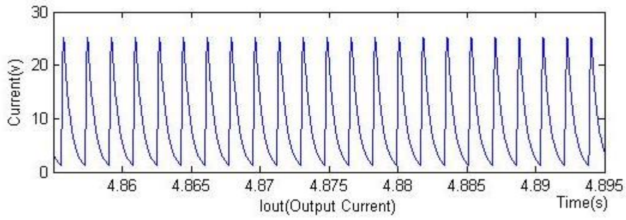

Fig 8 Output current

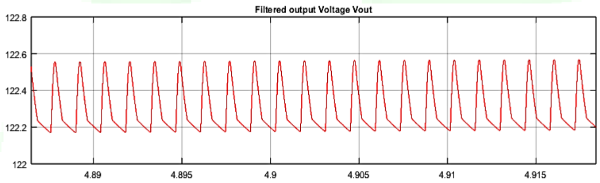

Fig 9 Output voltage

Figure 9 showing the output voltage waveform of the converter with open loop control. About 122.5 volt of voltage appears at the output or load end. Which is pretty good response of the converter.

D. Close Loop Converter

The closed loop lead-lag filter based, PID control of cascade converter is shown in Figure 10.

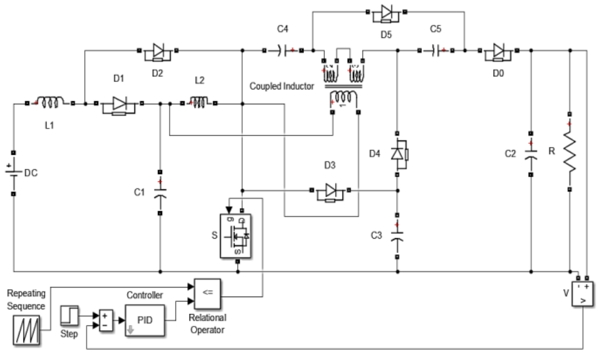

Fig 10 DC-DC Quadratic Boost Converter with PID Controller

The converter is controlled by the PID controller with the dedication to improve the boosting response. Charging and discharging of the capacitors depends on the switching patten for the dedicated switch. The average current is nearly 10 amperes.

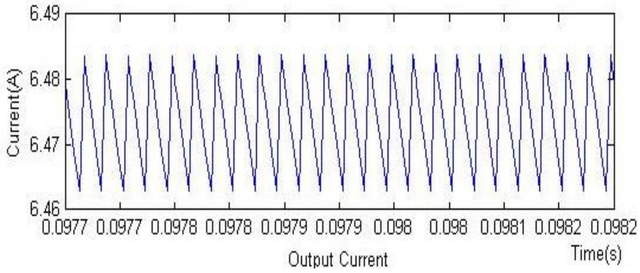

Fig 11 Output Current waveform of closed loop converter

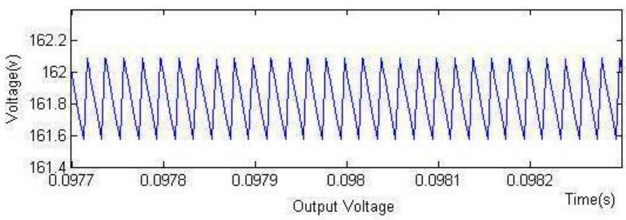

Fig 12 Output voltage waveform of converter for closed Loop control

Figure 12 shows the output current which is of minimum limit 6.45 ampere and maximum limit 6.485 ampere i.e., average current is 6.475 ampere. The average output voltage shown in Figure 12 is 161.8 volt. The minimum limit is 161.60 volt while upper limit is 162.00 volt.

In scope 3 of Figure 713 the PID controller response is shown, which is pulse form of .0015 second. The switch is operating at 50KHz.

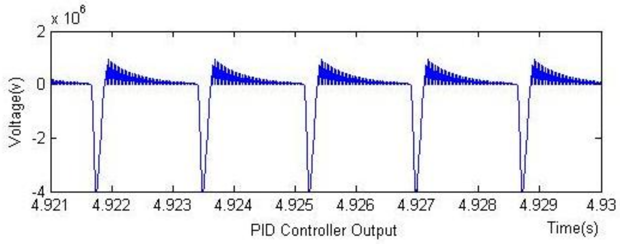

Fig 13 PID Controller Response

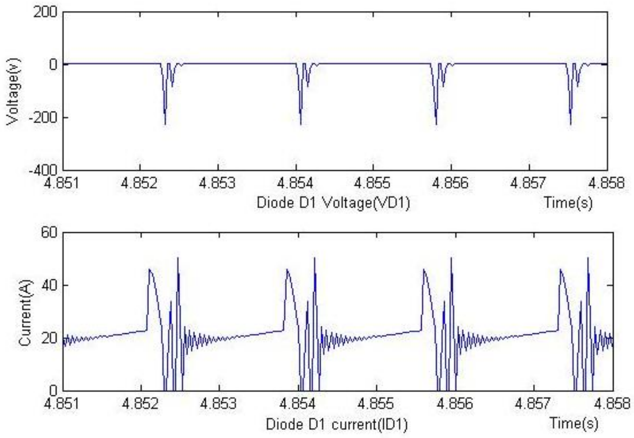

Fig 14 Diode D1 Current and Voltages Waveform

The diode voltages and current shown in scope 1 of Figure 14, from the wave forms it is very clear that the diode is acting as switch also and helping to energies inductor L1 for certain duration. Frequent variation in the current and voltage over the power electronic component i.e., diode, MOSFET, is termed as stress over these elements. Regarding current it is termed as current stress, while for voltage it is termed as voltage stress**Switched / Soft Switched Converters** - In power electronics, the switching properties of transistors in converters are referred to as hard-switched and soft-switched. Transistors undergo quick transitions between the on and off states when they turn on, which causes substantial switching losses and component stress.

All the numerical results are shown in Table 2 corresponding to the open and closed loop control of the proposed converter.

E. Results in tabled form

Table 2 open loop and close loop with and without compensator

Type	Vi (V)	Io(min) (A)	Io(max) (A)	Iavg (A)	Vout(max) (V)	Vout(Min) (V)	Vout(avg) (V)	Freq. (Khz)	Duty ratio
Open Loop	30	6.450	6.485A	6.475	162.00v	161.60	161.8v	50	0.65
Closed loop Without Comp.	30	2	25A	10	50V	220	200.25	50	0.8

F. Performance of Proposed Boost Converter System

S.no.	Performance parameter	Open Loop Parameters	Close Loop Parameters
1	Ripple voltage	0.4volt	0.25 volt
2	Ripple in current	0.035A or .54%	23 volt or 250%
3	Boosting	6.472 times	7.33 times

4	Operating frequency	50KH	50 kHz (average)
5	Efficiency	89.98%	96.65%

From the tabulated results above, it is clear that the boost provided by open loop converter is 6.472 times while the boost provided by close loop is 7.33 times. The ripple in voltage is found to be 0.4 volt in case of open loop and 0.25 volt in case of close loop system. The output voltage of open loop system is high because of working with duty ratio of 0.65. So, the voltage ripple is high and losses is more that causes efficiency is low i.e., 89.98% at .01-ohm active switch resistance. The output voltage of close loop system is high because of working with duty ratio of 0.8 only. The efficiency of system working in close loop system is high i.e., 96.65%.

V. CONCLUSION

This research article presented cascaded dc-dc boost converter driven by single switch is modelled and implemented successfully using MATLAB/ Simulink. The efficiency of the converter is 96.65% and step-up voltage gain is 2.25 times as compare to conventional method. Here in the ripples in output voltage is reduced up to 0.25V in case of close loop converter as compared to open loop which was at .40V. This converter eliminates the need of active snubber, auxiliary resonant circuit, synchronous rectifiers, or switched-capacitor-based resonant circuits and so on, that all are able to achieve soft switching on the main switch for reaching higher efficiency. Converter utilises the single switch there in the circuit, switching losses are reduced and switch will be safer from the stray heating.

In future the proposed converter can be used in different microgrid applications like: house hold solar power systems and fuel cell based electrical power generation systems. As high frequency switching is involved in boost converter, the transients are introduced in output voltage waveform. In soft switching or zero voltage switching (ZVS) the transients are mitigated or reduced. In future ZVS can be used with the proposed cascaded dc-dc boost converter to achieve better performance. In electric vehicle this type of dc-dc converters are appropriate and efficient because in the next generation we are going to electrify the vehicles completely so in this way it is required to design or model the advance and novel boost converters

References

[1] Elghabsi, Farag, Mohd Rodhi Sahid, Razman Ayop, Ahmed Alanssari, Mohammad Al Takrouri, Mahmood Swadi, Masoud A. Sahhouk, Hasmat Malik, and Vinay Kumar Jadoun. "High gain and high efficiency soft switching quadratic boost converter for renewable energy applications." *Scientific Reports* 15, no. 1 (2025): 36238.

[2] Coelho, Sergio, Vitor Monteiro, and Joao L. Afonso. "Topological advances in isolated DC–DC converters: High-efficiency design for renewable energy integration." Sustainability 17, no. 6 (2025): 2336.

[3] Lin, Chang-Hua, Mohammad Suhail Khan, Javed Ahmad, Hwa-Dong Liu, and Tung-Chun Hsiao. "Design and analysis of novel high-gain boost converter for renewable energy systems (RES)." Ieee access 12 (2024): 24262-24273.

[4] Begum, Khaja Shahini, B. Dharmasa, M. Ramprasad Reddy, and Bathina Rajesh Kumar. "A Study of High Gain DC-DC Boost Converters for Renewable Energy Sources." Int. J. Electr. Electron. Res 12, no. 2 (2024): 409-414.

[5] Shayeghi, H., S. Pourjafar, S. M. Hashemzadeh, and F. Sedaghati. "A dc-dc converter with high voltage conversion ratio recommended for renewable energy application." Journal of Operation and Automation in Power Engineering 12, no. 3 (2024): 186-194.

[6] Mansour, Arafa S., and Mohamed S. Zaky. "A new extended single-switch high gain DC–DC boost converter for renewable energy applications." Scientific Reports 13, no. 1 (2023): 264.

[7] Gnanavadivel, J., K. Jayanthi, S. Vasundhara, K. V. Swetha, and K. Jeya Keerthana. "Analysis and design of high gain DC-DC converter for renewable energy applications." Automatika: časopis za automatiku, mjerenje, elektroniku, računarstvo i komunikacije 64, no. 3 (2023): 408-421.

[8] Mansour, Arafa S., AL-Hassan H. Amer, Elwy E. El-Kholy, and Mohamed S. Zaky. "High gain DC/DC converter with continuous input current for renewable energy applications." Scientific Reports 12, no. 1 (2022): 12138.

[9] Ramanathan, J. G. G. & Urasak, N. Non-isolated interleaved hybrid boost converter for renewable energy applications. Energies 15(2), 1–14 (2022)

[10] Paula, W., Oliveria, D. S., Pereira, D. C. & Tofoli, F. L. 'Survey on non-isolated high-voltage step-up dc-dc topologies based on boost converter'. IET Power Elect. 8(10), 2044–2057 (2015)

[11] Malik, M., Ali, A. & Kumar, D. A two cascaded boost converter with high voltage gain module. Int. J. Comput. Electr. Eng. 9(2), 476–483 (2017).

[12] Karthikeyan, V., Kumaravel, S. & Gurukumar, G. High step-up gain DC–DC converter with switched capacitor and regenerative boost configuration for solar PV applications. IEEE Trans. Circuits Syst. II Exp. Briefs 66(12), 2022–2026 (2019)

[13] Kumar, A. et al. A high voltage gain DC–DC converter with common grounding for fuel cell vehicle. IEEE Trans. Veh. Technol. 69(8), 8290–8304 (2020).

[14] Axelrod B., Berkovich Y. & Ioinovici, A. Switched capacitor (SC)/switched inductor (SL) structures for getting hybrid step-down Cuk/Sepic/Zeta converters. In IEEE International Symposium Circuits Systems, Kos, Greece, 5063–5066 (2006).

[15] Axelrod, B., Berkovich, Y. & Ioinovici, A. Switched capacitor/switched inductor structures for getting

transformerless hybrid DC–DC PWM converters. IEEE Trans. Circuits Syst. Reg. Pap. 55(2), 687–696 (2008).
[16] Tewari, N. & Thazhathu, S. Family of modular, extendable and high gain dc–dc converter with switched inductor and switched capacitor cells. IET Power Elect. 13(7), 1321–1331 (2020)
[17] Lu, J., Stegen, S. & Butler, D. High frequency and high-power density transformers for DC/DC converter used in solar PV system. In IEEE 2nd International Symposium on Power Electronics for Distributed Generation Systems, Hefei, China 481–484 (2010)..
[18] Suryadevara, R. & Parsa, L. Full-bridge ZCS-converter-based high-gain modular DC–DC converter for PV integration with medium-voltage DC grids. IEEE Trans. Energy Conv. 34(1), 302–312 (2019)..
[19] Joseph, P. & Devaraj, E. Design of hybrid forward boost converter for renewable energy powered electric vehicle charging applications. IET Power Electron. 12(8), 2015–2021 (2019)
[20] Bilsalam, A., Boonyaroonate, I. & Chunkag, V. High-voltage gain zero-current switching push–pull resonant converter for small energy sources. IET Power Electron. 9(4), 835–845 (2016)
[22] Mizani, M., Ansari, S. A., Shoulaie, A., Davidson, J. N. & Foster, M. P. ‘Single-active switch high-voltage gain DC–DC converter using a non-coupled inductor’. IET Power Electron. 14(2), 492–502 (2021).
[23] Abbasi, M., Nazari, Y., Abbasi, E. & Li, L. A new transformer-less step-up DC–DC converter with high voltage gain and reduced voltage stress on switched-capacitors and power switches for renewable energy source applications. IET Power Electron. 14(7), 1347–1359 (2021)

