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# Simulation of a Single-Switch High-Gain DC-DC Converter with Active Switched Inductor

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**ABSTRACT:** Renewable energy systems like photovoltaic (PV) panels and fuel cells generate low, variable DC voltages that must be stepped up efficiently for grid or vehicle applications. This study presents a simulation-based analysis of a compact, non-isolated DC–DC converter featuring a single-switch configuration and an active switched inductor (ASI) mechanism, designed to deliver high voltage gain without relying on transformer-based solutions. A quadratic boost front-end and an ASI cell are combined to achieve a gain of  $(1+D)/(1-D)^2$  in continuous conduction mode. Key components (inductors, capacitors, IGBTs, and diodes) are selected to handle a 24–34 V input while minimizing ripple and stress, particularly accommodating the IGBT's higher voltage handling and slightly slower switching compared to MOSFETs. The converter is modelled in MATLAB/Simulink under open-loop control (300  $\Omega$  load, 60 kHz switching). Dual-mode operation is analysed: Mode I (switch ON) charges inductors and redistributes energy via capacitors; Mode II (switch OFF) transfers stored energy to the output. Steady-state waveforms confirm that inductor currents rise in Mode I and fall in Mode II, yielding a nearly constant output voltage with small ripple. At moderate duty ratios (e.g., 0.6–0.7), the proposed converter achieves a substantial voltage increase, potentially reaching several hundred volts—while maintaining a continuous input current. High efficiency (around 90%) is sustained, thanks to minimized voltage stress and well-regulated switching dynamics, with the IGBT's superior voltage-blocking capability helping manage stress at high output voltages. Compared to conventional boost or buck–boost converters, the ASI-based topology achieves superior voltage gain even at moderate duty cycles, aligning well with design expectations and performing competitively when compared to recent converter architectures in existing studies. Future work may integrate closed-loop control and hardware testing to validate dynamic performance.

**KEYWORDS:** DC–DC Converter, High Voltage Gain, Active Switched Inductor, IGBT Switching, Quadratic Boost Converter, Renewable Energy Systems, MATLAB/Simulink Simulation.

## I. INTRODUCTION

Modern renewable sources (e.g., PV panels, fuel cells) produce DC voltages that are often low and fluctuating. To interface with grids or loads requiring higher voltages, compact high-gain converters are essential. In particular, single-stage converters with a high step-up ratio can eliminate intermediate stages and transformer size, improving power density and efficiency. As noted by Kumar et al., high voltage gain and efficiency are crucial for low-voltage renewables to avoid additional power stages. Efficient energy conversion ( $\approx 90\%$ ) is also a key goal to minimize losses, and using robust switching devices like IGBTs helps handle high voltage stress efficiently.

## II. LITERATURE SURVEY

Many recent works propose novel high step-up converters. Revathi and Prabhakar provided a comprehensive review of such topologies for PV systems. For fuel-cell and EV applications, Bhaskar et al. surveyed dozens of non-isolated converter schemes. Active switched-inductor converters have shown excellent performance; for example, Wang et al. integrated an ASI configuration with additional auxiliary circuits to minimize input current ripple while significantly improving voltage conversion efficiency. Qin et al. proposed a boost–SEPIC structure with ASI units, using soft-switching resonant tanks to achieve  $\sim 18\times$  gain and  $\sim 97\%$  efficiency ( $24\text{ V}\rightarrow 445\text{ V}$ ). Naik and Vinatha (2024) introduced the NSSHG-ASI converter (quadratic boost + ASI) for fuel cell and PV systems, achieving compact design and continuous currents. These designs show ASI and related cells effectively boost voltage and suppress current pulses. While many designs use MOSFETs as the main switch, IGBTs offer an alternative with superior voltage-blocking capacity, making them suitable for high-voltage, moderate-frequency operation.

## III. METHODOLOGY

### A. Component Selection

The converter uses one IGBT switch, three inductors ( $L_1$ – $L_3$ ), four capacitors ( $C_1$ – $C_4$ ), and four diodes ( $D_1$ – $D_4$ ). Inductors are sized for sufficient energy storage at a  $24$ – $34\text{ V}$  input, ensuring continuous-conduction mode (CCM) and minimal current ripple. Capacitors are selected to limit voltage ripple ( $<1\%$  of nominal) and distribute voltage stress. The IGBT is chosen for its superior voltage-blocking capacity, despite slightly higher switching losses compared to MOSFETs. Fast-recovery power diodes minimize switching and reverse-recovery losses.

### B. Circuit Modelling

The topology consists of a quadratic boost stage ( $L_1$ – $C_1$ – $D_1$ ,  $D_2$ ) feeding an ASI cell ( $L_2$ ,  $L_3$ ,  $C_2$ – $C_4$ ,  $D_3$ ,  $D_4$ ) and output stage. MATLAB/Simulink is used for modelling under open-loop control with a  $300\ \Omega$  resistive load and  $60\text{ kHz}$  switching frequency. Performance metrics include voltage gain, component stresses, efficiency, and ripple, with simulations across duty cycles.

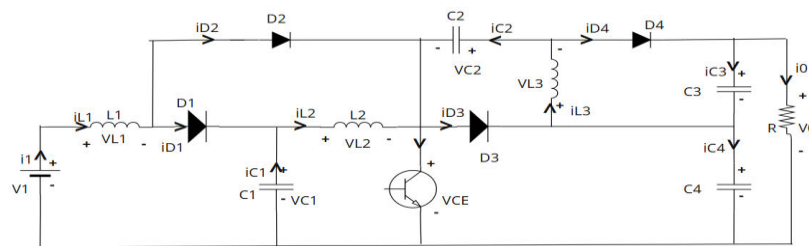


Fig (a): Circuit Diagram

### C. Operating Principle

In Mode I (switch ON),  $L_1$  charges from the input,  $L_2$  charges from  $C_1$ , and  $L_3$  charges from  $C_4$ ;  $C_3$  and  $C_4$  supply the load.

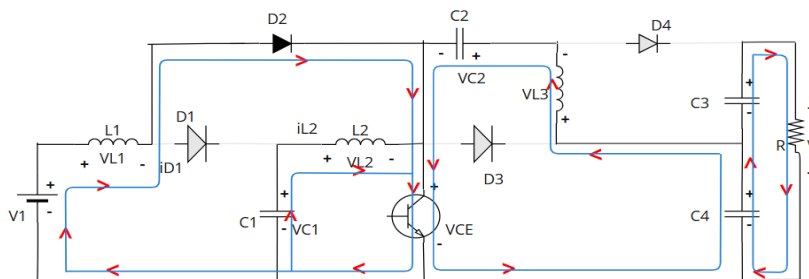


Fig (b): Mode 1 operation

In Mode II (switch OFF),  $L_1$  releases energy into  $C_1$ ,  $L_2$  into  $C_4$ , and  $L_3$  into  $C_2/C_3$  and the load. The steady-state DC gain in CCM is:  $V_o/V_{in} = (1 + D) / (1 - D)^2$ .

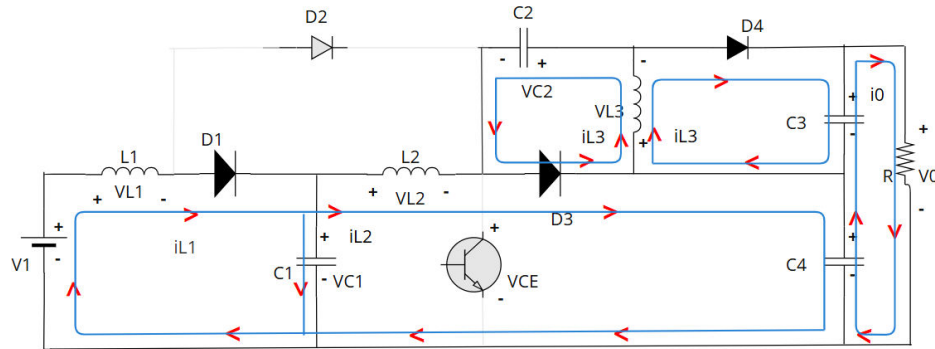


Fig (c): Mode 2 operation

#### IV. EXPERIMENTAL RESULTS

Simulations were conducted in MATLAB/Simulink to evaluate the converter's performance across an input voltage range of 24–34 V under a 300  $\Omega$  resistive load and a 60 kHz switching frequency. The output voltage ranges from 140 V to 200 V, confirming the theoretical gain. The output voltage ripple remains below 1%, and all energy storage components operate in continuous conduction mode (CCM). The input current (Fig. 3) is continuous and smooth, highlighting the converter's suitability for renewable energy applications.

The detailed behaviour of internal signals such as inductor currents, switch dynamics, and diode/capacitor voltages during the two operating modes is analysed as follows:

##### A. Inductor Currents

1. During Mode-I ( $t_0$ – $t_1$ ), the currents through inductors  $L_1$ ,  $L_2$ , and  $L_3$  (Figs. 5–7) increase linearly as energy is stored. In Mode-II ( $t_1$ – $t_2$ ), these currents decrease as energy is released into capacitors and the load. The slope of each waveform is influenced by input voltage, inductance, and load parameters.

##### B. Switch Voltage and Current

The IGBT switch conducts current with near-zero voltage across it during Mode-I. In Mode-II, the switch turns OFF, and its drain-to-source voltage (Fig. 24) rises according to the converter's voltage gain, while the switch current (Fig. 23) drops to zero.

##### C. Diode Behaviour

In Mode-I,  $D_1$ ,  $D_3$ , and  $D_4$  are reverse-biased (Figs. 19, 21, 22 show zero current), while  $D_2$  is forward-biased and conducts (Fig. 20). In Mode-II,  $D_1$ ,  $D_3$ , and  $D_4$  conduct, and  $D_2$  becomes reverse-biased with current ceasing and voltage increasing.

##### D. Capacitor Dynamics

The capacitor currents and voltages (Figs. 11–18) show slight ripples consistent with periodic charging and discharging. In Mode-I,  $C_1$  and  $C_4$  discharge to supply energy to  $L_2$ ,  $L_3$ , and the load.  $C_2$  and  $C_3$  stabilize the output. In Mode-II,  $C_1$  is recharged by  $L_1$ , and  $C_4$  is partially recharged by  $L_2$ .

##### E. Voltage and Current Profiles

The input voltage (Fig. 1) and output voltage (Fig. 2) show regulated conversion. The output current (Fig. 3 .4) is stable, and ripple remains within acceptable limits. Inductor voltages (Figs. 8–10) and capacitor voltages (Figs. 15–18) confirm efficient energy transfer and filtering.

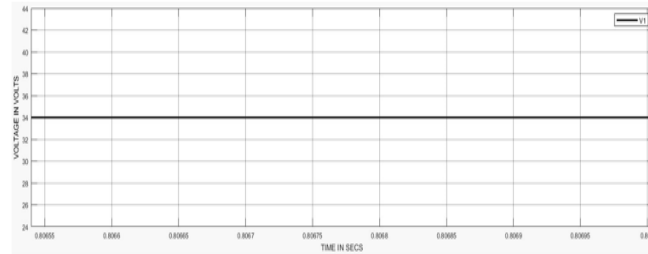


Fig 1: Input voltage

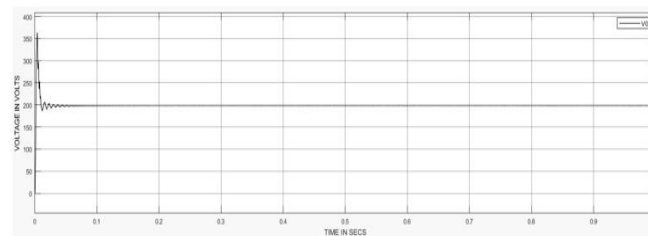


Fig 2: Output voltage

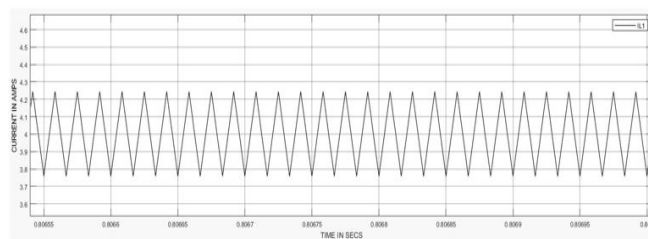


Fig 3: Input Current

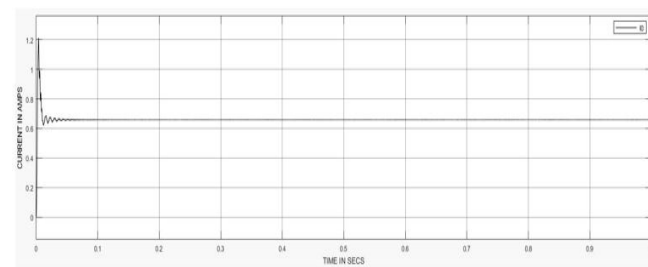


Fig 4: Output Current

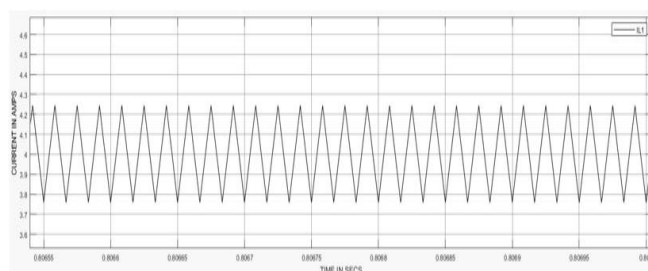


Fig 5: Inductor 1 Current

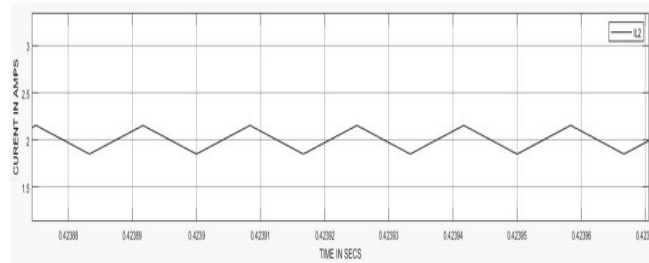


Fig 6: Inductor 2 Current

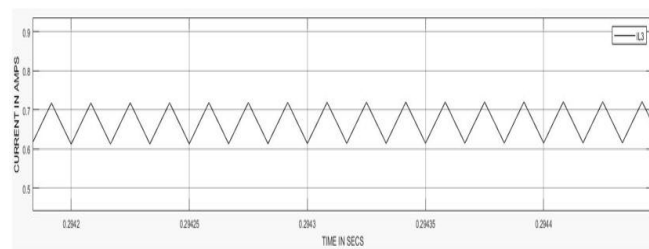


Fig 7: Inductor 3 Current

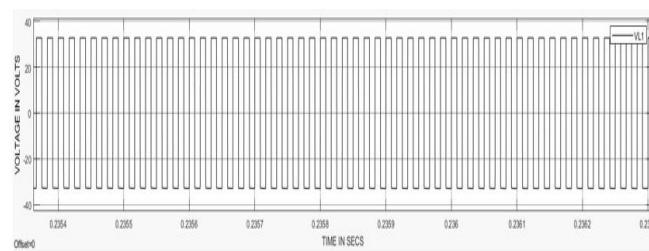


Fig 8: Inductor 1 voltage

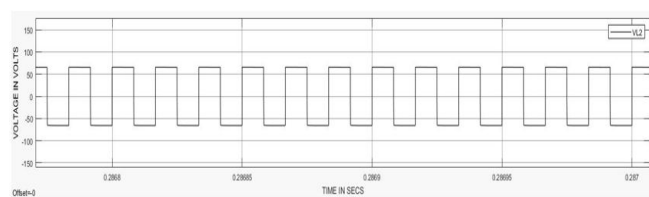


Fig 9: Inductor 2 Voltage

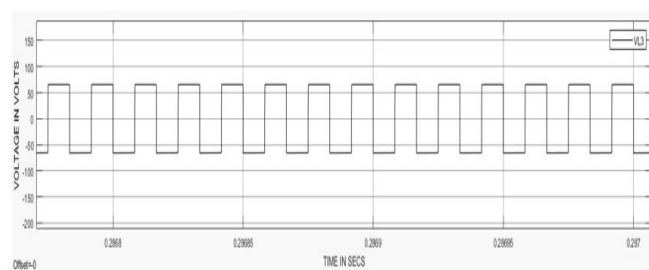


Fig 10: Inductor 3 Voltage

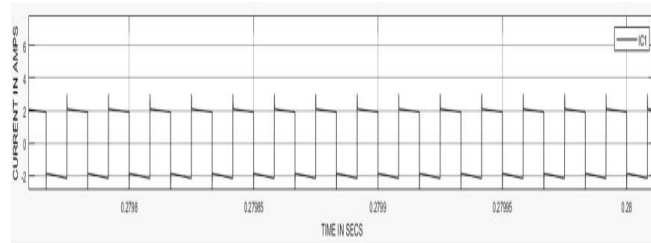


Fig 11: Capacitor 1 Current

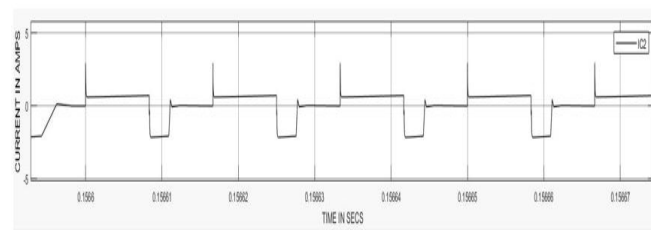


Fig 12: Capacitor 2 Current

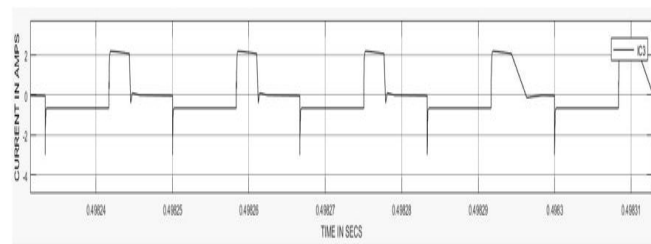


Fig 13: Capacitor 3 Current

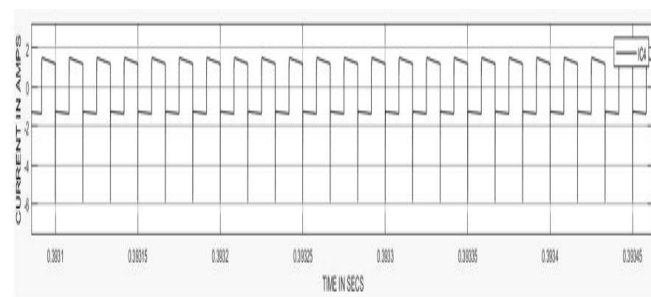


Fig 14: Capacitor 4 Current

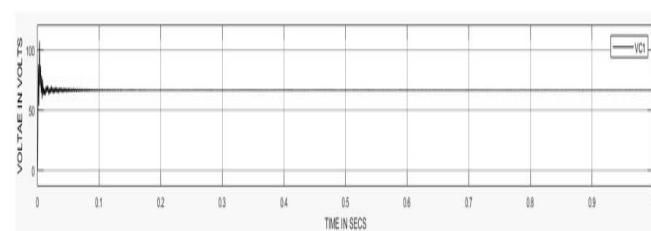


Fig 15: Capacitor 1 voltage

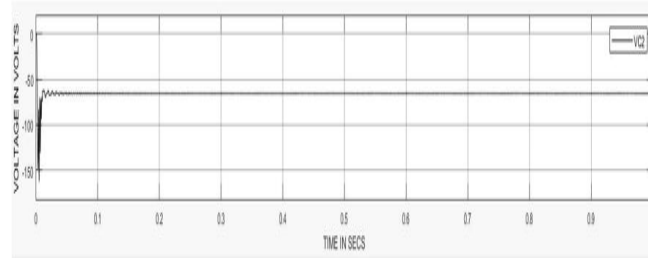


Fig 16: Capacitor 2 voltage

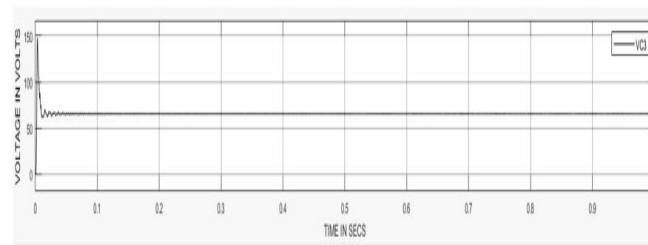


Fig 17: Capacitor 3 voltage

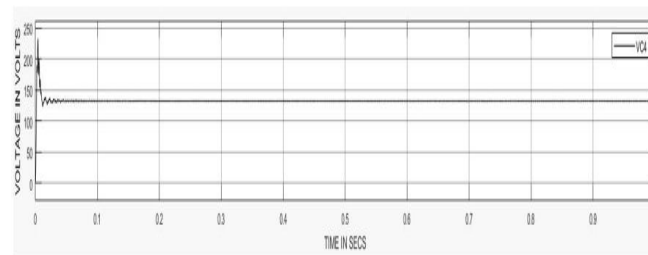


Fig 18: Capacitor 4 voltage

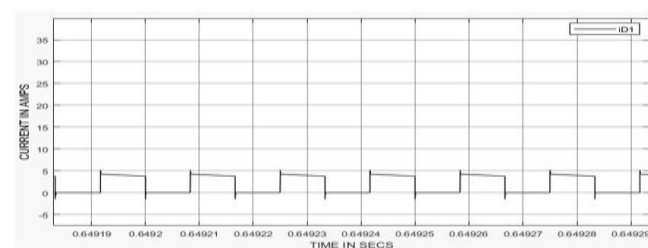


Fig 19: Diode 1 current

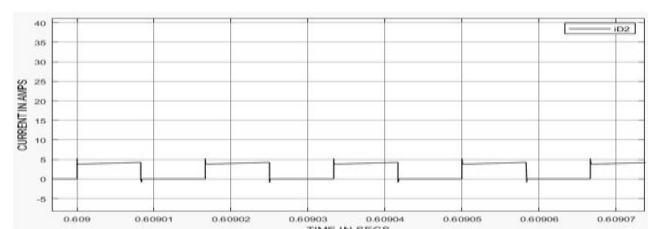


Fig 20: Diode 2 current

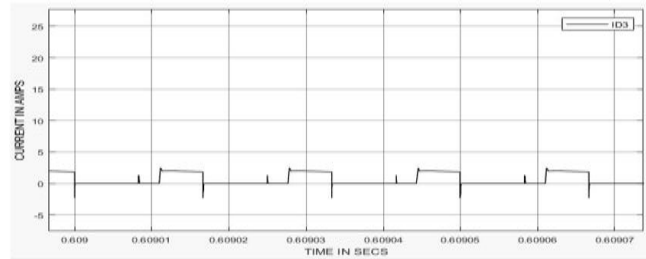


Fig 21: Diode 3 current

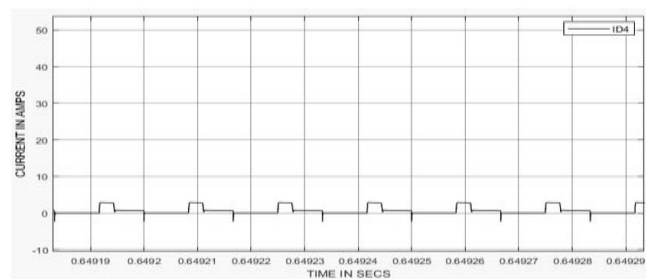


Fig 22: Diode 4 current

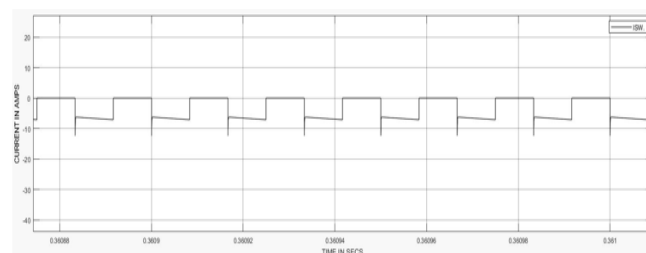


Fig 23: IGBT current

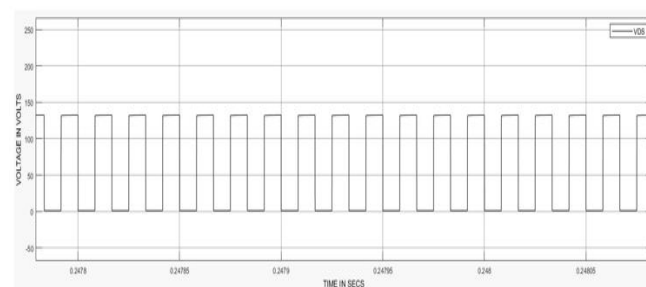


Fig 24: IGBT voltage

## V. CONCLUSION

This paper presents the design and simulation of a single-switch, high-gain DC–DC converter using an ASI network and IGBT. The topology achieves high voltage gain with continuous input/output currents at moderate duty cycles, making it well-suited for renewable energy systems. MATLAB simulations confirm the theoretical predictions and show excellent boosting performance with low ripple. Future work will focus on closed-loop control, efficiency optimization, and hardware testing to evaluate dynamic performance.

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S Jnanesh from Bangalore, currently pursuing BE in Electrical and Electronics at BIT, India gained practical PLC automation knowledge during his internship at GTTC, interests include Python and problem-solving enhancing in technical aptitude.

Mithunkumar K S from Bangalore, currently pursuing BE in Electrical and Electronics at BIT, India, experienced in PLC, SCADA, VFD testing, rewinding, and automation. Completed internships, technical projects, and hands-on roles at ABB. Skilled in MATLAB, troubleshooting, and electrical inspections with strong technical and coordination abilities.

Alok Kumar from Bangalore, currently pursuing BE in Electrical and Electronics at BIT, India. Gaining knowledge in Data Structures and Algorithms, along with practical understanding of core electrical engineering concepts. Skills include problem-solving and coding, contributing to growth in both software and hardware domains.



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