

High Gain Three Port DC-DC Converter

Koushika Elavarasi T R¹, Govindaraju C²,

¹M.E Student/ PED/ Government College of Engineering / Salem-11.

²Associate Professor / EEE / Government College of Engineering / Salem-11.

Abstract - This paper presents the design and analysis of a high-gain non-isolated three-port DC–DC converter for renewable energy applications. The proposed topology integrates a photovoltaic (PV) source, a battery storage system, and a high-voltage DC load within a single power conversion stage. By employing a coupled inductor and switched-capacitor network, the converter achieves a high voltage gain while maintaining reduced voltage stress across semiconductor devices. The converter operates in multiple modes including PV-only operation, battery support mode, dual-input mode, and battery charging mode, ensuring continuous power delivery under varying environmental conditions. The proposed design reduces component count and improves efficiency compared to conventional multi-stage converters. Simulation and hardware validation confirm the effectiveness of the system in achieving high voltage gain, stable output, and efficient energy management.

Key Words: Three-port converter, high-gain DC–DC converter, coupled inductor, renewable energy, battery charging, switched capacitor.

1.INTRODUCTION

The increasing demand for efficient renewable energy systems has led to the development of multi-port DC–DC converters capable of integrating multiple energy sources and storage elements. Conventional systems typically use multiple converters for power conditioning, which increases system complexity, cost, and losses.

Three-port converters (TPCs) provide a compact solution by enabling power flow between multiple sources and loads using a single-stage architecture. However, many existing designs suffer from limitations such as high voltage stress, complex control strategies, and reduced efficiency at high gain levels.

To overcome these issues, this paper proposes a high-gain non-isolated three-port DC–DC converter using a coupled inductor and switched-capacitor network. The topology

achieves high voltage gain without requiring extreme duty cycles while maintaining reduced component stress and improved efficiency.

2. Proposed Converter Topology

The proposed converter integrates three ports:

- Renewable energy source (PV)
- Battery storage system
- High-voltage DC output

The circuit consists of three active switches (S_1 , S_2 , S_3), multiple diodes, capacitors, and a coupled inductor. The coupled inductor plays a key role in boosting voltage and transferring energy efficiently between ports.

It is often important to refer back (or forward) to specific sections. Such references are made by indicating the section number, for example, “In Sec. 2 we showed...” or “Section 2.1 contained a description...” If the word Section, Reference, Equation, or Figure starts a sentence, it is spelled out. When occurring in the middle of a sentence, these words are abbreviated Sec., Ref., Eq., and Fig.

At the first occurrence of an acronym, spell it out followed by the acronym in parentheses, e.g., charge-coupled diode (CCD).

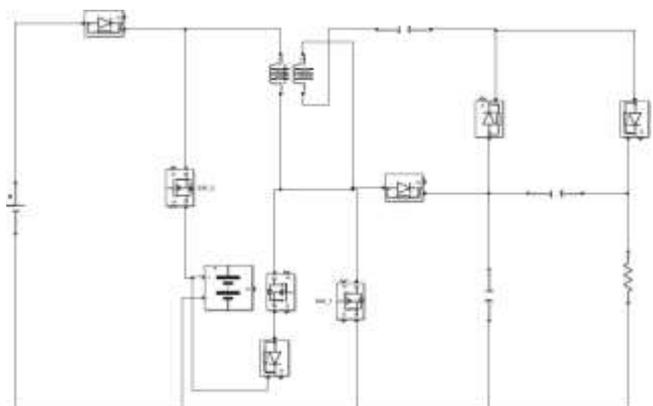


Fig.1 Circuit Diagram of Proposed Converter

The converter operates based on controlled switching of MOSFETs, enabling bidirectional power flow between the battery and load while allowing unidirectional power transfer from the PV source.

2.1. Detailed Operating Modes of the Proposed Converter

Mode I ($t_0 - t_1$): Energy Storage from PV Source

- Switch State: S_1 ON, S_2 OFF, S_3 OFF
- Diodes: Input-side diodes conduct, output diodes are reverse-biased

Operation:

- The PV source supplies energy to the magnetizing inductance L_m of the coupled inductor.
- Current flows from PV $\rightarrow S_1 \rightarrow$ primary winding \rightarrow ground.
- The inductor current i_L increases linearly.
- Output capacitor supplies energy to the load during this interval.

Mode II ($t_1 - t_2$): Energy Transfer to Secondary and Capacitor Charging

- Switch State: S_1 OFF, S_2 ON, S_3 OFF
- Diodes: Secondary-side diodes conduct

Operation:

- When S_1 turns OFF, stored energy in the coupled inductor is released.
- Due to transformer action, voltage is induced in the secondary winding.
- Capacitors (e.g., C_2, C_3) are charged through diodes.
- Energy is transferred to both output and intermediate capacitors.

Mode III ($t_2 - t_3$): Combined Energy Delivery to Load

- Switch State: S_1 OFF, S_2 OFF, S_3 ON
- Diodes: Output-side diodes conduct

Operation:

- Charged capacitors and inductor release energy to the load.
- Output capacitor is charged to a higher voltage level.
- Load receives energy from:
 - Inductor
 - Charged capacitors (stacked voltage effect)

Mode IV ($t_3 - t_4$): Battery Charging Mode

- Switch State: S_1 ON, S_2 OFF, S_3 ON
- Condition: PV power $>$ load demand

Operation:

- Excess energy from PV is diverted to charge the battery.
- Current flows through battery charging path via controlled switch S_3 .
- Output voltage remains regulated while battery absorbs surplus energy.

Mode V ($t_4 - t_5$): Battery Discharging Mode

- Switch State: S_1 OFF, S_2 ON, S_3 ON
- Condition: PV power insufficient

Operation:

- Battery supplies energy to support the load.
- Energy flows from battery \rightarrow inductor \rightarrow output.
- Converter operates in boost mode using battery as input source.

Mode VI ($t_5 - t_6$): Freewheeling Interval

- Switch State: All switches OFF (or minimal conduction path)

Operation:

- Inductor current continues through diodes (freewheeling path).
- Prevents sudden current drop and reduces switching stress.
- Ensures smooth transition between modes.

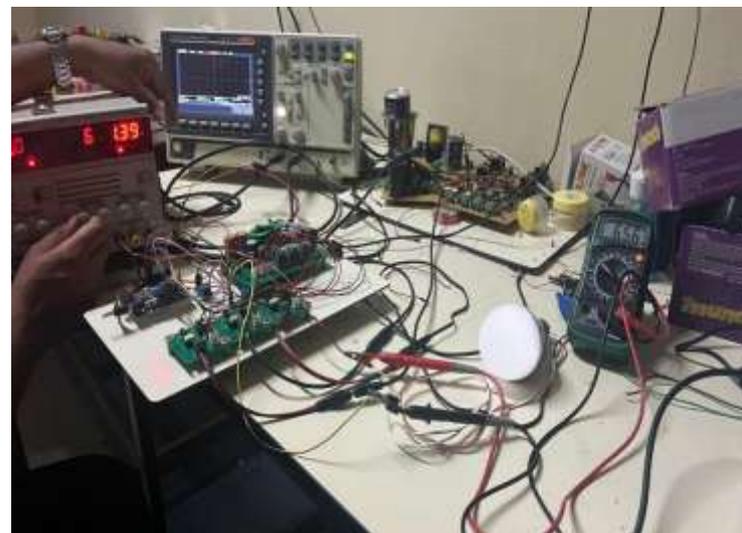


Fig.2: High Gain Three Port Dc-Dc Converter

2.2.PCB And Layout Considerations

This is where most students mess up badly.

- High-current paths are kept short to reduce losses
- Proper grounding is implemented to avoid noise issues
- Switching loop area is minimized to reduce EMI

- Heat sinks are used for MOSFETs

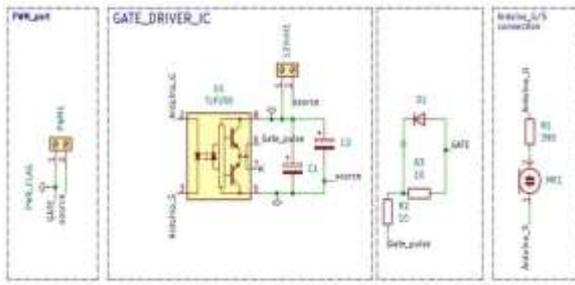


Fig.3 Fabricated PCB / Gate Driver Board

3. SIMULATION RESULTS

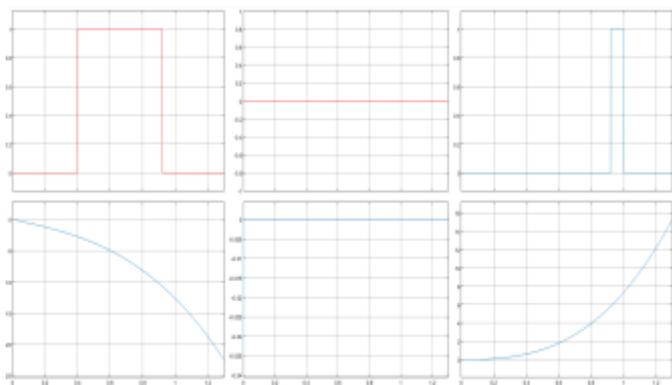


Fig.4 Waveform of dual input mode

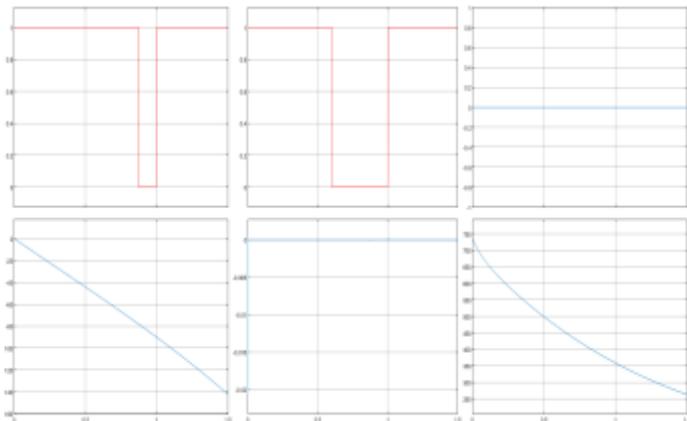


Fig.5 Waveform of battery charging mode

3. CONCLUSIONS

A high-gain non-isolated three-port DC–DC converter has been designed and implemented for renewable energy systems. The proposed topology effectively integrates PV, battery, and load within a single-stage conversion system. The use of a coupled inductor and switched-capacitor network enables high voltage gain, reduced component stress, and improved efficiency. The multi-mode operation ensures reliable performance under

varying conditions. This converter is suitable for applications such as electric vehicles, standalone solar systems, and hybrid energy storage systems.

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