International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 09 Issue: 04 | April - 2025 SJIF Rating: 8.586 ISSN: 2582-3930

# Design of Bi-directional Buck Boost Converter

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## ABSTRACT

In the era of renewable energy and electric vehicles, bidirectional power conversion has become a crucial aspect of energy management systems. This paper presents a simulation-based design of a bidirectional buck-boost DC-DC converter regulated by a PID controller. The converter enables both charging and discharging operations between a DC source and a battery, ensuring efficient power transfer and regulation under varying load and voltage conditions. The system is model and simulated using MATLAB/Simulink, and its performance is evaluated in both operational modes. Key parameters such as output voltage, inductor current, and state of charge (SOC) are monitored to validate the system's stability and responsiveness

**Keywords:** Bidirectional Buck -Boost Converter, Battery, Charging ,Discharging, PID controller

## I.INTRODUCTION

Bidirectional DC-DC converters have gained prominence in applications requiring energy storage, such as electric vehicles, hybrid power systems, and uninterrupted power supplies. Unlike unidirectional converters, bidirectional converters support power flow in both directions, facilitating charging and discharging of energy storage systems.Among various topologies, the buck-boost converter offers the flexibility of stepping up or stepping down the voltage, making it ideal for interfacing between batteries and DC buses with varying voltage levels. To regulate the operation of such converters, Proportional-Integral-Derivative (PID) controllers are commonly used due to their simplicity and effectiveness.

This paper focuses on the modeling and simulation of a bidirectional buck-boost converter using a PID controller in MATLAB/Simulink. The control strategy dynamically adjusts inductor current based on the mode of operation—charging or discharging—ensuring accurate voltage regulation and efficient power transfer.

## II.METHODOLOGY

The proposed methodology involves the design, modeling, and control of a bidirectional DC-DC converter using PI controllers in MATLAB/Simulink. The converter is intended to manage energy transfer between a DC source (such as a battery) and a DC load, operating efficiently in both charging and discharging modes. The control system is structured to automatically regulate current and voltage according to the load demand and battery state of charge (SOC)

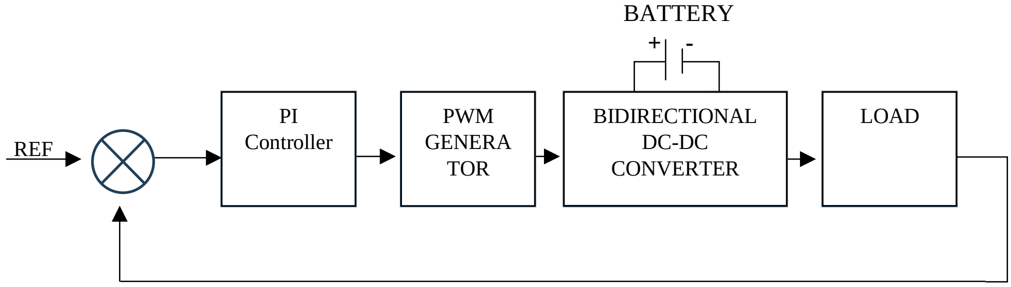


Fig 1. Block Diagram

**1)System Configuration**

The system comprises the following main components:

1) Bidirectional DC-DC Converter: Configured with two controlled switches to allow power flow in both directions. The converter operates in buck mode during charging and boost mode during discharging.
2) Battery Model: Acts as the energy storage system, capable of receiving or supplying power based on system requirements.
3) Load: A variable DC load that consumes power from the system.
4) Scope: Used to measure voltage, current, and SOC of the battery to provide feedback to the controllers.

.**2)Control Strategy** The converter employs a dual-mode PID control system to regulate the inductor current:

I. **Charging Mode (Boost Operation)**

When the battery is to be charged, the system enters boost mode.The reference current is generated by comparing a fixed set voltage (e.g., 26 V) with the actual output voltage.A PID controller regulates the current $I_{charge}$ , which in turn controls the gate signals to the MOSFETs.The current is boosted and stored into the battery.

**II. Discharging Mode (Buck Operation)**

When discharging, the converter steps down the battery voltage to power the load (e.g., maintaining 48 V).The PID controller regulates the discharging current $I_{discharge}$ , based on a voltage feedback loop.The MOSFETs switch appropriately to allow power flow from the battery to the output.

**MODELING AND ANALYSIS**

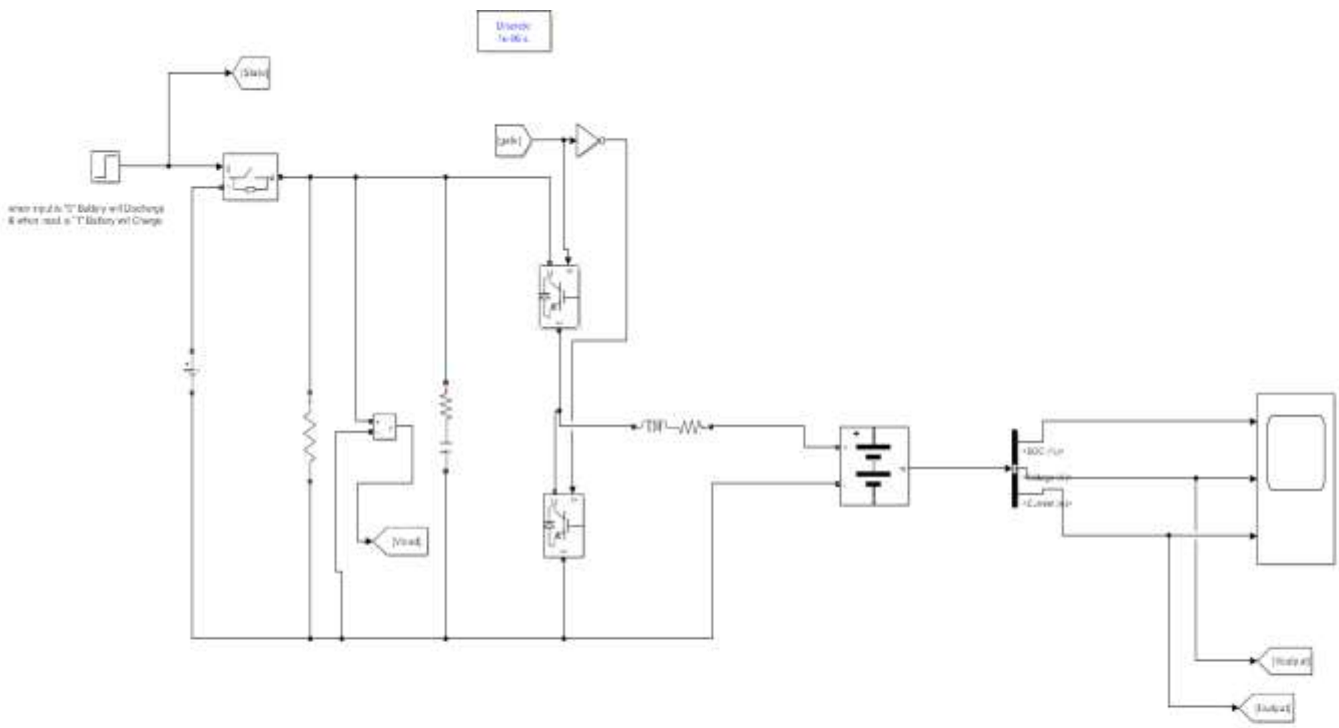

**Figure 2:** Simulation Model of Bidirectional Buck Boost Converter

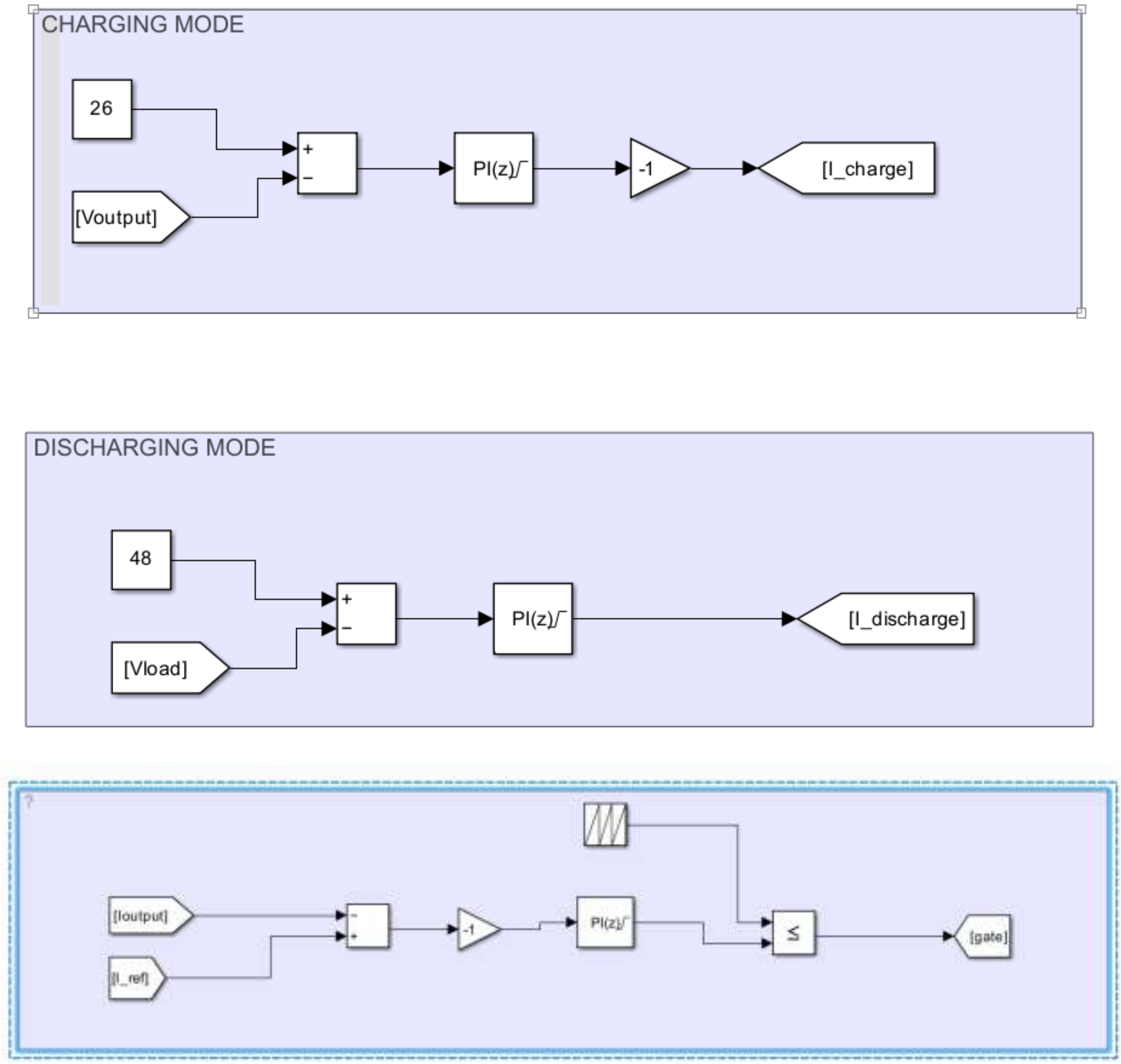


**Figure 3:**Control Strategies for the operation of Bidirectional Buck Boost Converter

## III.CONVERTER OPERATION

The bidirectional DC-DC converter is designed to enable power flow in both directions—either from the source to the battery (charging) or from the battery to the load (discharging). This dual functionality allows the system to adapt dynamically based on load demand and battery status. The converter operates in two primary modes: Buck mode and Boost mode

### 1) Buck Mode (Charging Operation)

In buck mode, the converter steps down the input voltage to charge the battery. This operation is typically initiated when the battery's state of charge (SOC) is low or when the input power supply is higher than the battery voltage. In this mode:

- One switch of the converter operates in a high-frequency switching pattern, controlled by a PWM signal.

- The other switch remains ON or acts as a freewheeling path.

- The inductor stores energy during the ON state and releases it during the OFF state, providing a smooth charging current to the battery.

The PI voltage controller maintains the battery voltage at a desired reference level by adjusting the charging current through the current controller, ensuring safe and controlled charging.

### 2) Boost Mode (Discharging Operation)

When the load requires more power than the input can supply, or when regenerative energy needs to be harvested (e.g., in electric vehicles during braking), the converter switches to boost mode. In this case:

- The battery becomes the source, and the converter steps up the voltage to match the load requirements.

- The switching pattern is reversed, with the appropriate switch being controlled by the PWM signal to regulate power delivery.

- The inductor plays a key role in storing energy from the battery and releasing it at a higher voltage to the load.

The PI voltage controller ensures that the output voltage remains stable despite fluctuations in load. The current controller fine-tunes the energy delivery by maintaining current within the prescribed range.

### 3) Mode Transition

A logical control block continuously monitors system parameters such as battery SOC and output voltage. Based on predefined conditions, it decides whether the system should operate in buck or boost mode. The transition between modes is handled smoothly to avoid voltage or current spikes, ensuring system reliability.

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## IV. RESULTS AND DISCUSSION

**State of Charge (SOC):** In the charging process, SOC of the battery rose steadily, affirming successful energy storage. In the discharging process, SOC reduced steadily, showing successful delivery of energy to the load.

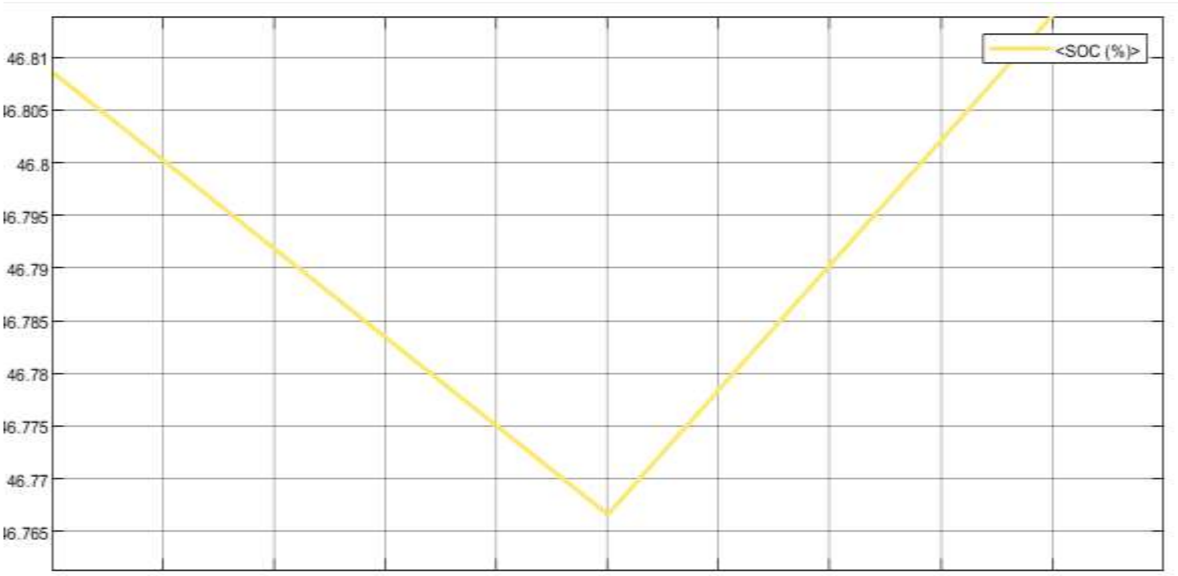


**Figure 4.** %Soc of the Battery During Discharging and Charging Mode

**Battery Voltage**: The battery voltage was stable and in accordance with the reference values throughout both operating modes. Voltage rose in the charging process and fell in the discharging process, as expected.

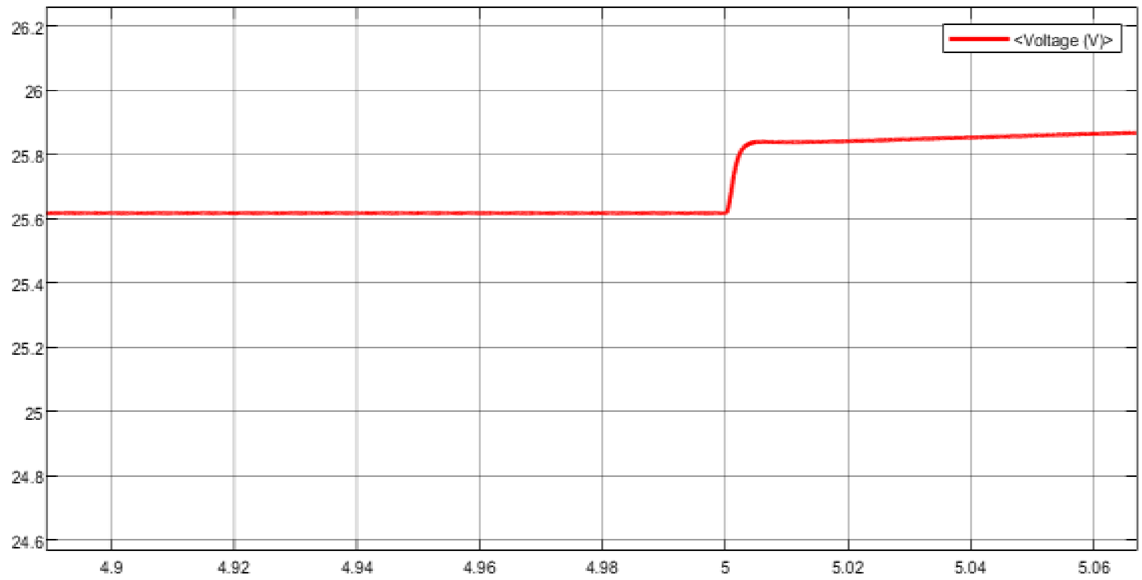


**Figure 5.** Battery Voltage During Discharging and Charging Mode

**Battery Current**: The simulation exhibited regulated and smooth current transitions. In charging, the current rose in a controlled fashion, and in discharging, it stayed within safe levels, demonstrating the efficiency of the current regulation system.

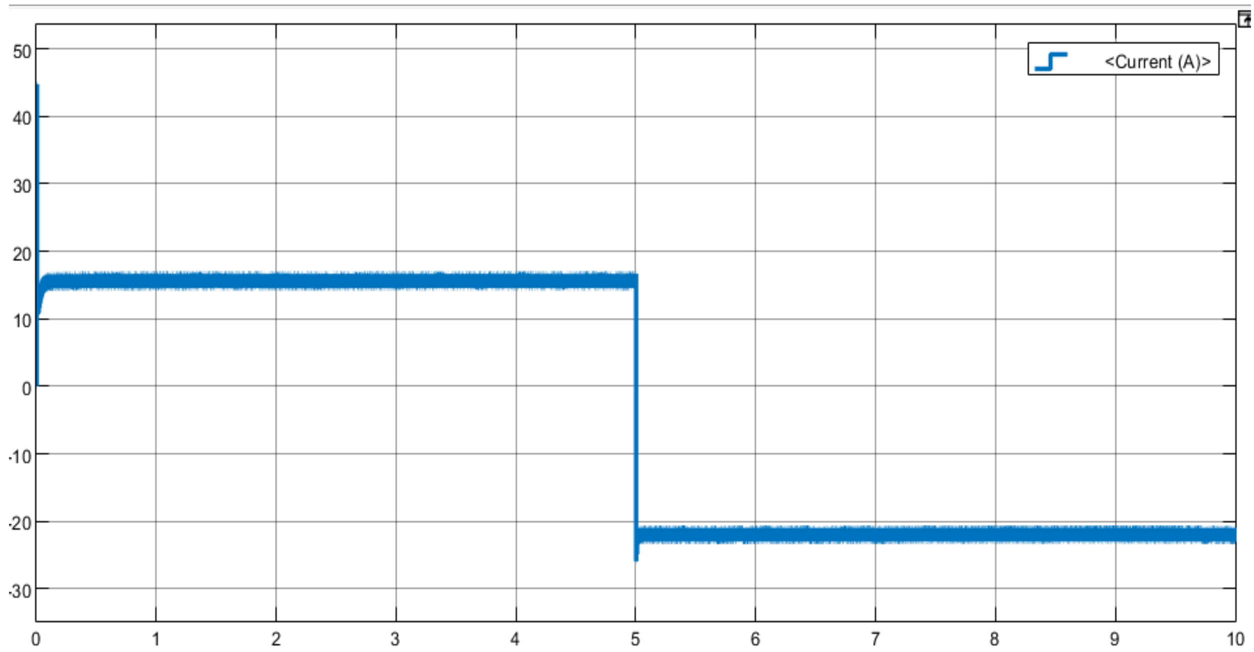


**Figure 6.**Battery Current During Discharging and Charging Mode

## V.CONCLUSION

The bi-directional DC-DC converter effectively manages power flow between a DC source and a battery, operating reliably in both charging and discharging modes. By utilizing controlled switching and feedback-based regulation, the system ensures efficient energy transfer with minimal losses. The use of PI controllers for both modes allows precise current regulation, contributing to the stability and performance of the converter. This design is well-suited for electric vehicle applications, where bidirectional power flow is essential for charging the battery and supplying power to the drivetrain. Overall, the converter demonstrates robust and flexible operation, making it a key component in modern energy management systems

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