

Modelling of Bidirectional Buck-Boost DC-DC Converter in Electric Vehicles

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Abstract. The design of DC-DC converter in bidirectional mode focuses on achieving cost efficient, compact size, low switching losses. For future sustainable transportation, electric vehicles are crucial things, and Efficient Power management is required for advanced energy usage and better performance. A Bidirectional DC-DC Buck-Boost Converter is very important to Electric vehicle power systems because its energy flow between battery and the auxiliary load. Moreover, the converter's bidirectional capacity allows for regenerative braking, which leads to increased energy efficiency and prolonged the vehicle's range. Steady performance under a load range and input scenario is ensured by advanced control techniques like PWM and feedback control loop. For using wide-band gap semiconductor devices to enhance the systems performance and efficiency. The readings of Buck voltage and Boost voltage taken from the prototype and also analysed by Matlab Simulation. The buck, boost and voltage ripple will be minimized by the Matlab Simulink. There by increase the Efficiency of the system. From this energy efficient we will achieve the SDG 7 of affordable and clean energy.

Keywords: Converter, Electric Vehicles, Regenerative Braking, Energy Efficiency, Power Management- Matlab.

1. Introduction

The Bidirectional Buck-Boost converters allow the energy transfer in between the battery and electric vehicles other loads by electric vehicle energy management system. By this converter operation of boosting or bucking the voltage, assurance of the best possible performance from the electric vehicle's electrical system. Depending upon the load the battery voltage varies, the necessity of a steady and regulated power source. The buck-boost topology develops the EV sureness and

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reliability by sustaining appropriate voltage levels. Experimental this converter is main portion in this prototype, it assesses the Voltage Regulation, Efficiency of converter and transient reaction in EV's in dynamic environments. The existing system of traditional unidirectional DC-DC converters in EV is less efficient because there is bucking or boosting happening. The existing Cuk and Sepic buck-boost converters have large switching efficiency; lower efficiency and they have more components.

But the Bidirectional Buck-Boost Converter provides better efficiency by enabling bidirectional power flow, low conversion Losses. To ensure stable operation of EV components by better voltage gain. It has less components and more Less passive parts and a more space saving design than traditional existing converters. It has less switching stress by increased reliability. It highlights the benefits of this design over the current models as well as how it affects energy efficiency and voltage stability in electric car applications.

2. Material and Methodology

Proposed Converter transfers energy flow in between battery and electric vehicles motor by integral part of the electric vehicle energy management system. The Bidirectional converter, battery, switching devices in converter, power control unit, and motor and feedback control system are essential parts of this block diagram. Each block is necessary for beneficial power management and smooth operation. The main components of the battery block, which provides power to the motor in EV's when it is in propulsion mode and absorbs energy during regenerative braking. Battery's voltage swings based on its charge level so the converter is an essential part to control and maintain the exact voltage level. The component of converter block, allows power to flow both forward and reverse ways. This converter ensures the power obtained for vehicle drive by boosting voltage to a respected level for the electric vehicle motor that is in boost mode. The small amount of energy generated by regenerative breaking that flows back to the battery by bucking operation is shown in figure 1.

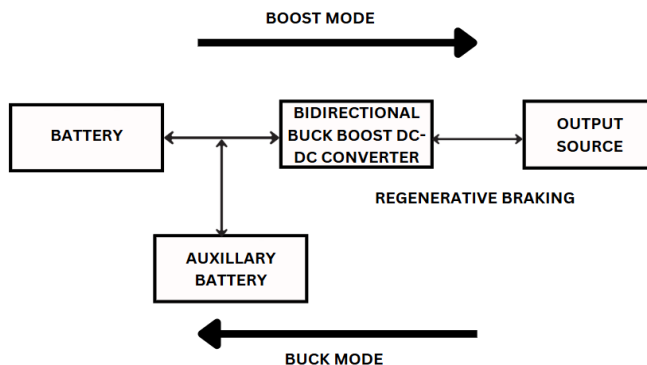


Fig 1. Methodology diagram

The switching device block consists of a IGBT, necessary for controlling the power flow. This semiconductor switch is high frequency. It is used to check whether it is operating in Boost mode or buck mode. The time period of switches in correspondence with the necessary voltage, current level controlled by a PID controller built within the control unit block. The control system continues the optimal power transmission by strongly changing the switching pulses to provide authentic voltage conversion.

The output source of an electric motor requires varying voltage by depending on vehicle speed and load circumstances. Electric vehicles need to run effectively because the converter makes sure the motor gets the electricity. During regenerative braking the converter uses the flow of energy from the motor into the system, reducing the waste and increasing overall performance.

The feedback block, which endlessly checks the voltage and current levels at different places in the circuit, is an important part of the system. By feedback control, the real-time modifications are made possible, which ensures that the output still has a constant value even when input values change. The detected voltage and current data by sensors to adjust the time period of the switches. This block diagram the Protection methods of overvoltage, overcurrent, and thermal protection circuits are also integrated. By preventing stress on components, these safety features develop the durability and accuracy of EV. It is perfect for applications that require energy improvement, increase the battery life and lower dependence on external charging sources by bidirectional converter.

Table 1. Feature of proposed Converter over than traditional Converter

Features	Bidirectional Buck Boost Converter	SEPIC converter	CUK converter
Bidirectional Power Flow	Achieved	Not Possible	Not Possible
Inductor Count	1	2	2
Control Simplicity	Easily Control	Very Difficult to Control	Very Difficult to Control
Size and Component Count	Small	Large	Large

3. Result and Discussion

3.1 System Design and Modelling

The experimental value and simulation of a converter for Powerful energy management in EV applications is the main aim of the research. By using this converter, the power flows between the battery and motor drive, which gives ideal voltage gain and enhanced energy efficiency. This system aims to rectify the conventional unidirectional converters, such as restricted energy flow and incapable voltage adaptation shown in figure 2.

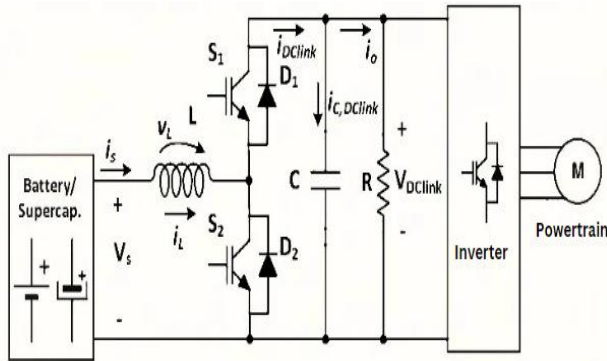


Fig 2. Circuit Configuration diagram

A) Voltage Step-up Process:

If the motor has higher voltage than the input of battery voltage then our proposed converter increases the voltage to confirm the reliable power delivery to the motor. When IGBT1 is switched ON during high frequency then it allows energy stored in the inductor. Then stored energy is released, when IGBT1 is switched off, then boosting voltage is sent to the motor.

$$V_{out} = \frac{V_{in}}{1-D} \quad (1)$$

B) Voltage Step-Down Process:

In order to properly charge the battery and ensure effective power recovery, the converter lowers the voltage when the motor runs at a higher voltage than the battery. When IGBT2 is turned on and off, energy can move from the motor to the battery at a lower voltage. To avoid excessive variations in the charging voltage, the inductor controls the flow of current.

$$V_{out} = V_{in} \cdot D \quad (2)$$

3.2. Hardware and Software Architecture in Matlab Simulation

The developed prototype consists of:

1. A converter can operate in both steps up and step down mode.
2. The operational mode is controlled by a microcontroller based on system requirements.
3. The energy is stored in a battery bank.
4. The load motor represents an EV motor.
5. IGBT switches, relays and driver circuit are used in the power electronics section for efficient switching.
6. For safety purposes, supporting transformer and isolation circuits are included in the design.

Both boosting and bucking the potential of voltage are possible with a converter shown in figure 3(a). Additionally, it functions both ways:

1. Power moves from the battery to the load (discharge mode) via the motor.
2. Power moves from the load back to the battery through regenerative braking from the motor.

Modes of Operation

Buck Mode (motor powered by battery)

High battery voltage 12V is reduced to the lower voltage 9.38V that the motor needs shown in figure 3 (b).

Boost Mode (braking with regeneration)

Motor functions as a generator, stepping up from 8V to charge 18.8V battery figure 3 (c).

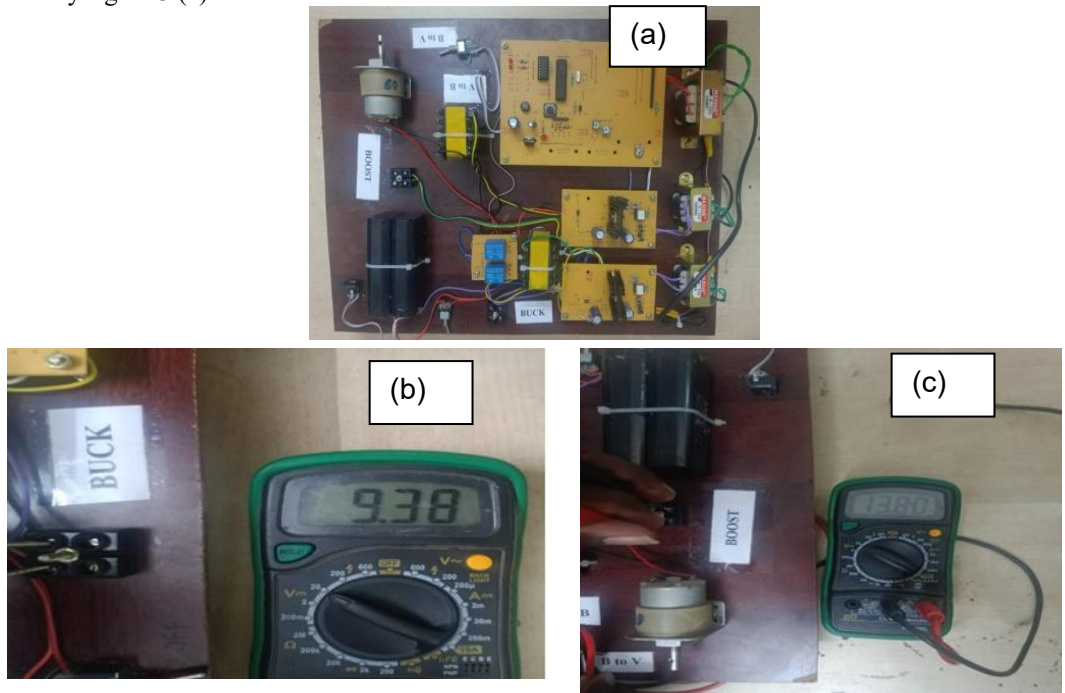


Fig 3. Hardware prototype.

3.3. Simulation

MATLAB/Simulink model for converter is intended to investigate regulation of power flow between a battery and an electric vehicle motor drive. The simulation demonstrates how the converter steps up (in boost mode) and steps down (in buck mode) the voltage to satisfy load requirements. When in Boost Mode, the battery (21.69V) powers the converter. Current can flow through the inductor and store energy when the IGBT switch is activated. Switch off condition, the motor receives the stored energy from the inductor to load. Output side of the voltage (173.5V), which is more than input side voltage, verifies the boost operation shown in Figure 4. In the Step-down process, the motor voltage is stepped down to charge the battery. Controlled energy transfer to the battery is possible by reversing the switching sequence. Through current flow regulation, the inductor guarantees smooth voltage conversion. The diagram's arrangement, Discrete Mode with a time step of 1e-6s is used to capture fast switching transients. Simulation time and reliability are balanced definitions of switching frequency. PID tuning is adjusted to maintain a consistent output voltage. Sensors for voltage and current gauge how well the system monitors power flow shown in figure 5.

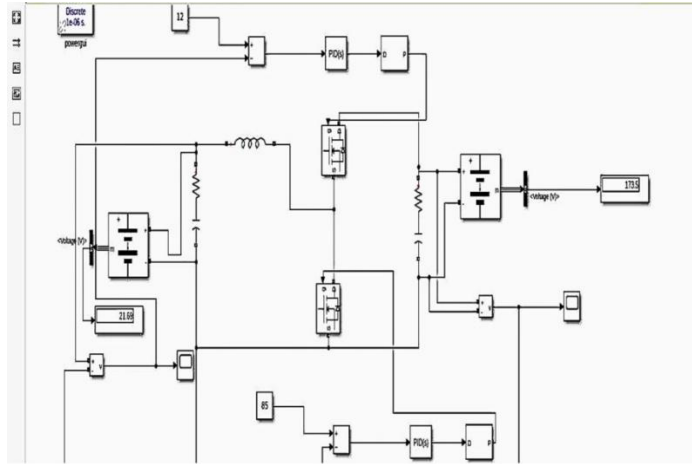


Fig 4. Simulation Design in Matlab/Simulink

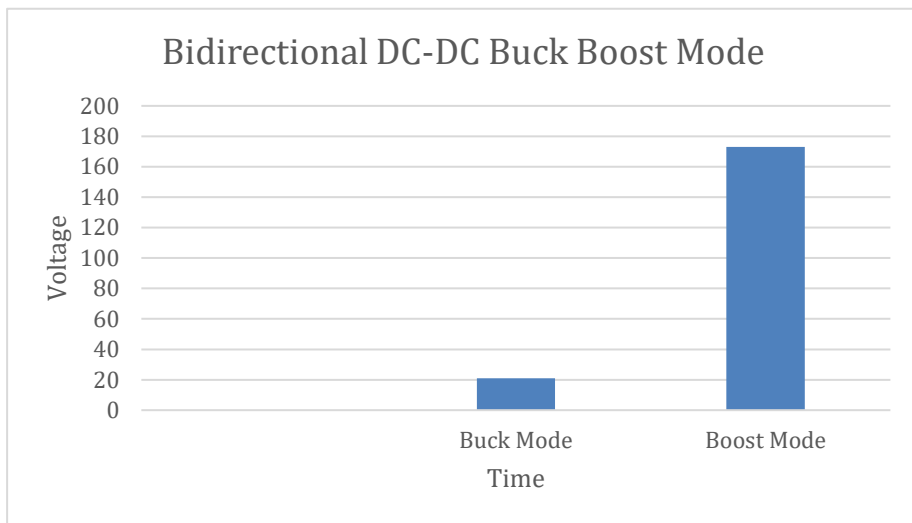


Fig 5 Boost operation & Buck Operation result

The performance of a converter for energy management in electric vehicles (EVs) is analysed through simulation using MATLAB/Simulink. The converter raises the battery voltage to the necessary level for the motor while it is in Boost Mode (Battery to Load). The motor's excess energy is transformed back into a lower voltage and stored in the +9battery while it is in Buck Mode (Load to Battery Regenerative Braking). The output appears on 0.8 seconds. In figure 5, the peculiarities of the battery cell input voltage. The input voltage is constant at first but dynamically varies according to cycles of charging and draining. The time period of this converter affects the potential profile and also illustrates how energy is transferred to the motor by displaying output input voltage. Operational mode affects the voltage; buck mode lowers the voltage, whereas boost mode raises it. Here too,

the output appears on 0.8 seconds. At the point where the two modes transition, there is a noticeable step change in the voltage level. Using Matlab Simulation, the operation is analysed to efficient power flow in both directions. Switching techniques are used to properly manage the voltage levels. Stable power transfer between the battery and motor is guaranteed by the system. The Efficiency of this converter is 90-95% due to Bidirectional power flow; less energy storage component compares to conventional converter.

Table 2. The result analysis of proposed Converter

Result	Bidirectional Buck Boost Converter	SEPIC converter	CUK converter
Input Voltage	12V	12V	12V
Boost Voltage	Up to 173V	Up to 120V	Up to 135V
Buck Voltage	Up to 9V	Up to 9V	Up to 9 V
Current	3.5A	3.5A	3A
Efficiency	90-95%	70-75%	75-77%
Ripple	Low ripple is achieved due to Proper Capacitor	High ripple achieved due to complex capacitor coupling	High ripple achieved due to coupling cannot be optimized.

Conclusion

The proposed converter for electric vehicle energy management has been experimentally verified in Prototype and simulated in MATLAB/Simulink. This converter has a very high ability to do the power flow control between battery and the motor, assured high performance in both motor drives and regenerative braking modes and it is done by simulation. To verify the smooth vehicle running, the converter boosts the voltage level to satisfy the motor load. On the other hand, during bucking mode, it generates energy during regenerative braking and transfers it and is stored in batteries of electric vehicles. Therefore, increase the energy efficiency and achieved the SDG 7. The graph shows the system's steady voltage shifts and this converter's power flow control. Additionally, this converter increases electric vehicle efficiency and achieved the SDG 13 of climate action. By minimal losses was achieved. The transient response is fast because of PID controlled switching. High efficiency is achieved in this converter power transfer. By capacitor limited filtering, the Voltage ripple is minimized.

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