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A Study of Bidirectional Electric Vehicle Charging using MATLAB Simulink

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Abstract

On considering Electric Vehicles, the rise of Vehicle-to-Grid(V2G) concept has been accompanied with lots of advantages. The V2G technology ensures that no extra electricity needs to be consumed from the grid. It helps the power grid on a larger scale. It enables a bidirectional power flow between the EV battery and the grid. Bidirectional Buck- Boost Converter helps in grid stabilization, financial gains, and effective energy management. The DC-DC Converter does two functions: matching the battery voltage to the motor's rated voltage and controlling power flow under steady-state and transient conditions. The Proportional-Integral (PI) controller is used to correct the errors between commanded set point and the actual value based on feedback. The efficiency of the converter can be increased by using PI controller.

Keywords: Bidirectional DC-DC converter, G2V, V2G, electric vehicle applications.

1. Introduction

Electric vehicles with bidirectional charging offer owners a valuable opportunity to sell excess energy back to the grid, effectively turning their vehicles into flexible energy sources

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and potentially generating revenue. When compared to unidirectional chargers, bidirectional chargers are more flexible in nature. Though it's quite complex and costly to setup, it has its own benefits. Bidirectional charging along with smart charging will help us towards the ease of human living. The Bidirectional Buck Boost Converter works in two modes they are: Conversion from AC (Alternating Current) to DC (Direct Current) which refers to charging i.e. buck mode of operation and the power conversion from DC (Direct Current) to AC (Alternating current) and that refers to discharging i.e. boost mode of operation [1]. The Buck Converter is a DC- DC, step-down converter used to reduce the input voltage for the required load. whereas the Boost Converter is a DC–DC step-up converter used to increase the input voltage for the required load [2].

The Non – Isolated DC – DC power converter we use, is better than Isolated DC – DC Converter which will be bulky and expensive [3]. The control method we use here is PI controller, phase-locked loop (PLL) Single Phase. Two IGBT Switches are used. The simulation is done using MATLAB. The battery voltage, battery current and grid voltage, grid current and SOC results are obtained and verified. This research focusses mainly towards the design, modelling and simulation of Bidirectional Buck Boost Converter for EV Applications. As for the Vehicle – Home (V2H) and Vehicle – Grid (V2G) is considered this method would be beneficial as it can help power all the home appliances and even medical devices if needed in case of blackouts or in case of emergency[4, 10]. This eliminates the need for generators or storage devices.

2. Block Diagram

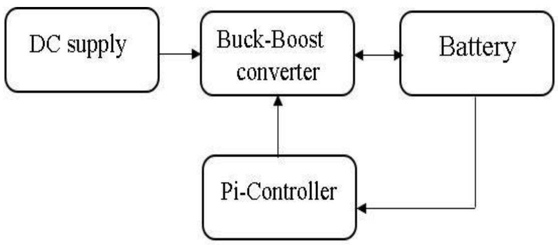

Figure 1. Block Diagram of Bidirectional Charger

Fig. 1 shows the block diagram of Bidirectional buck boost converter.

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A. DC Supply

A 12V DC Supply is used for boost operation and a 24V DC Supply is used for buck operation.

B. Buck-Boost Converter

In Fig. 2, circuit diagram of the buck-boost converter is shown. The bidirectional buck-boost converter also incorporates power electronic switches and control circuitry to enable bidirectional power flow. It allows power to flow from the input side to the output side or vice versa, depending on the voltage and power requirements. This bidirectional capability is useful in applications such as energy storage systems, electric vehicle charging, and regenerative braking systems. The bidirectional buck-boost converter can operate in two modes: step-up (boost) mode and step-down (buck) mode, depending on the voltage requirements and power flow direction [5].

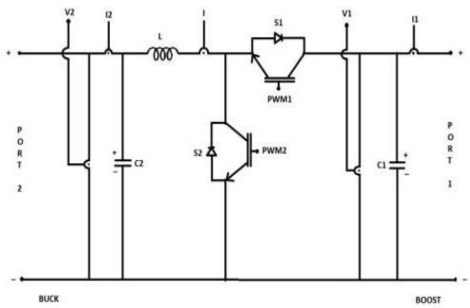

Figure 2. Circuit Diagram of Buck-Boost Converter

C. PI Controller

A Proportional-Integral (PI) controller is a fundamental component in control systems design, widely utilized in various feedback applications for its simplicity and effectiveness. The PI controller consists of two main components: the proportional gain (Kp) and the integral gain (Ki). This feedback loop continuously adjusts the control input based on the error signal, effectively regulating the system's output to track the desired setpoint or trajectory [6].

In PI Controller two values will be taken into account. One will be the constant value to which the battery’s output voltage during charging mode i.e. buck mode of operation. The same goes for battery's output current too, while the voltage is measured from the load side during discharging mode i.e. boost mode of operation.

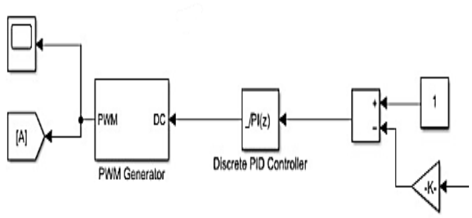

Figure 3. PI controller

The duty cycle determines the percentage of time the signal is ON, while the frequency determines how often the signal repeats within a given time period.

3. Simulation Results

The circuit is developed and simulated in the MATLAB SIMULINK platform. The simulation circuit and the results obtained are mentioned in this section.

A. Converter in Buck Mode

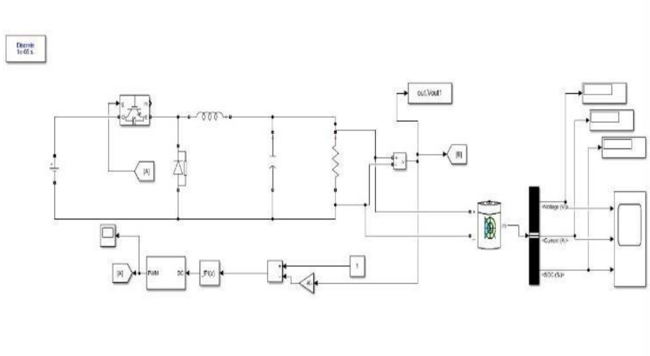

Figure 4. Simulation Circuit in Buck Mode

In a bidirectional DC/DC converter during Buck mode, a 24V DC supply is given as the input to port 1 as stated in the bidirectional converter topology. Then the output voltage is stepped down to 12V as obtained in Fig. 4. Hence, this mode is known as grid to-vehicle mode. Fig. 5 shows the output results in buck mode. The simulation design parameters are listed in Table.1

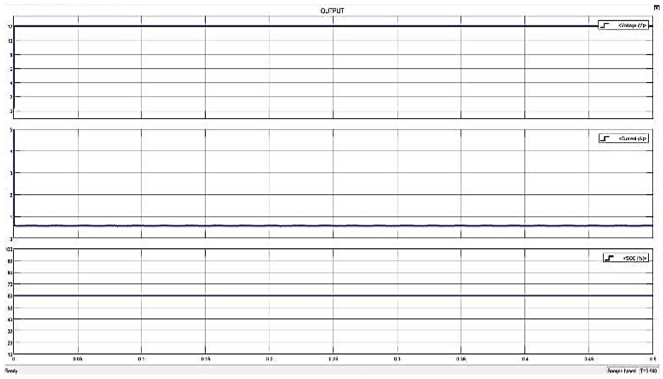

Figure 5. PI Controller Output Voltage and SOC

During Buck mode of operation, an input of 24V is given. The inductor and capacitor starts charging during ON time. Free-wheeling action takes place using the Free-Wheeling Diode the energized inductor and capacitor starts discharging to the battery. Free-Wheeling action takes place during OFF.

In Fig. 5 the PI Controller will take two input values, one is the output voltage of the battery and the other is a constant value which we have to fix. These two values will be added by summing and the result that will be given to the PI Controller in which the Kp and Ki values will be generated. This Kp and Ki values will be fed back to the PWM g enerator. Pulse Width Modulation (PWM) generation is a technique used in electronics to control the power delivered to a load by varying the duty cycle of a square wave. PWM works by rapidly switching a digital signal ON and OFF at a fixed frequency time. The given 24V will be stepped down and given to the battery as 12V, and it remains constant using PI controller [7].

Fig. 6 shows the simulation result of converter in Buck mode of operation. Batteries output voltage, output current ,and state of charge (SOC) are obtained and analyzed.

B. Converter in Boost Mode

In a bidirectional DC/DC converter during Boost mode, a 12V DC supply is given as the input to port 2 as stated in the bidirectional converter topology. Then the output voltage is stepped up to 24V as obtained in Fig.6. Hence this mode is known as a vehicle-to-grid mode.Fig.7 shows the output results in boost mode [8].

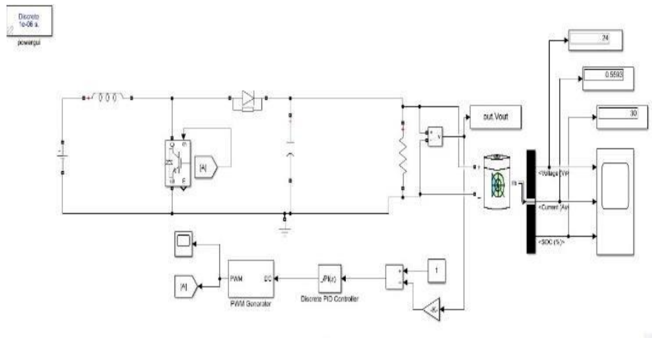

Figure 6. Simulation Circuit in Boost Mode

During Boost mode of operation, an input of 12V is given. The inductor starts charging during ON time and gets energized. The capacitor will get energize during OFF time. Free-wheeling action takes place when the energized capacitor starts discharging to the battery using the Free- Wheeling diode during OFF time. The given 12V will be stepped up and given to the battery as 24V, and it remains constant using PI controller[9].

Fig. 6 shows the simulation result of converter in Boost mode of operation. Batteries output voltage, output current, and state of charge (SOC) are obtained and analyzed.

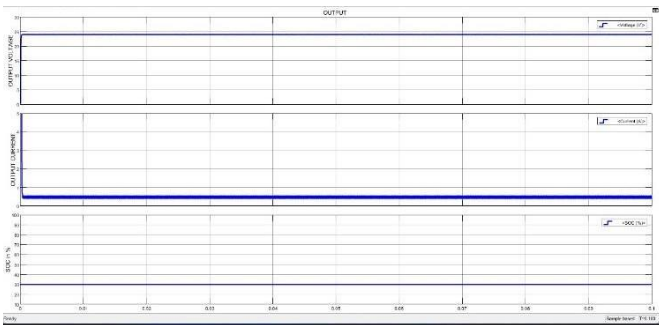

Figure 7. Output Voltage, Output current and SOC

Table 1. Simulation Design Parameters

Parameters	Buck	Boost
Input voltage	24V	12V

Output voltage	12V	24V
Inductor	1 mH	1mH
Capacitor	1000 µF	1000 µF
Resistor	15 Ω	50 Ω

4. Conclusion

The Simulation of Bidirectional Converter in Buck mode and Boost mode has been done separately. The output voltage, current, and SOC are measured, analyzed and obtained. Here the Converter has been designed separately as Buck Converter and Boost Converter meanwhile a full-fledged design for Bidirectional Buck – Boost Converter will be expected in future.

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