EV Battery Charging using Bi-directional Converter with Buck Mode

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***Abstract*—Bi-directional converters are essential in Vehicle-to Grid (V2G) applications. This converter plays a critical role in charging the battery by transferring energy from the grid to the Electric vehicle as well as discharging the battery by transferring energy from the electric vehicle to the grid when demand is high.The operation of a DC-DC bidirectional converter that charges the battery of an electric vehicle while in buck mode is examined in this paper. The bidirectional converter is under the control of a closed-loop PI control circuit. The MATLAB/Simulink environment is used to simulate the proposed bidirectional converter and the control circuit. A Proteus SPICE model is also utilised to simulate the gate drive circuit for the MOSFET switches used in the converter. The paper also presents various simulation results obtained. These results suggest that this converter can be used in multiple applications, including Vehicle-to-Grid (V2G) applications.**

Keywords—MOSFET, Bi-directional Convertors, V2G, Gate-drive, Bootstrap

I. Introduction

According to the REN21 Renewables 2023 Global Status Report, India is ranked fourth in the world for installed solar capacity, fifth for wind power generation capacity, and fourth for installed hydro capacity. The total installed capacity of renewable energy sources—including large hydropower—as of March 2024 is 190.57 GW[1].With the increasing trend of Electric powered vehicles on the road and the growing number of fast-charging infrastructure, there is a huge power demand introduced on the power grid. This demand is causing problems such as shortening of the equipment lifespan, higher short circuit currents, and voltage crossing the regulated limits. One of the challenges we encounter in trying to expand the capacity of the power system is the intermittent nature of renewable energy generation, which is dependent on the sun and wind. Renewable energy is also inexpensive and environmentally friendly. So when the supply can't meet the demand that's where the fossil fuel steps in and fills the gap. Since fossil fuels are non-renewable resources they will be depleted in the future.

With the help of a technology known as Vehicle to Grid (V2G), a car's battery may safely store energy, including renewable energy, and then release some of it back into the grid when it's most required. For example, a fleet of electric buses may be charged overnight during periods of low energy demand, driven according to schedule, and then use V2G to return energy to the grid while parked. Additionally, V2G enables the fusion of numerous cars' batteries to create a virtual power plant (VPP). The combined energy can then be used to supply so-called grid services—which stabilize the grid and avert blackouts—during peak hours or sold on energy markets. An opportunity for "vehicle-to-grid" (V2G) technology develops as more and more light vehicles switch to electric power. Through the use of this system, fuel cell electric vehicles, plug-in hybrid electric vehicles, or battery electric vehicles can communicate with the power grid to provide functions including regulation, spinning reserves, and peak power, all of which contribute to the stability of the grid . By doing so, V2G can help improve the power grid's efficiency, reduce the need for investment in power plants, and provide spinning reserves. V2G helps fleet owners by minimizing their expenses, such as helping them to power the buildings when required, as well as charging the fleet when electric prices are low.

An energy storage device is designed to collect and store energy from a power source. It then releases the stored energy to power things when needed. For safety reasons and to ensure a long lifespan, it's essential to manage how the device charges and discharges precisely. Typically, there are separate pathways for charging and discharging. These pathways serve different purposes, such as using a smaller current to charge and a larger one for discharging a lithium-ion battery. A bidirectional converter can seamlessly transition between charging and discharging by combining circuits. As a result, the system costs are decreased and the design is more compact. The solution offered by a bi-directional buck-boost converter is reliable and simple. This converter can be implemented in both isolated and non-isolated topologies. Non-isolated buck converters can work as boost converters in the opposite direction. Similarly, boost converters can work as buck converters in the opposite

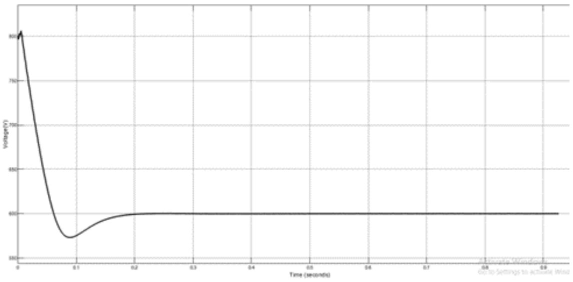

Fig. 13. DC bus voltage plot between Bus voltage in vertical y-axis and time(in seconds) in horizontal x-axis.

For the simulation of the gate drive circuit Proteus PSICE software is used. The specifications of the components utilized in the circuit are given in the below table (Table III).

TABLE III. SPECIFICATIONS OF THE GATE DRIVE CIRCUIT

Resistor (R1)	300ohms
Resistor (R2)	300ohms
Resistor (R3)	1000ohms
Resistor (R4)	330ohms
Capacitor (C1) - Booststrap capacitor	30nF
MOSFET	IRFZ44N

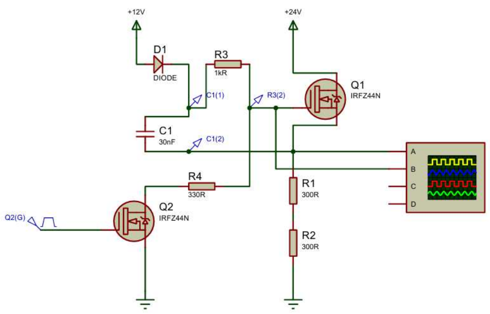

Fig. 14. Proteus schematic circuit of the proposed gate drive circuit of the High-side MOSFET switch.

Figure 14 shows a circuit where Q1 is the high-side power MOSFET and Q2 is a logic MOSFET that is present at the low-side position. By controlling the low-side Q2 switch, we can control the high-side Q1 switch. When the Q2 switch is turned on, the gate voltage of the Q1 switch is pulled down to zero, and capacitor C1 will be discharged. When the Q2 switch is turned off, capacitor C1 will start charging, thereby increasing the voltage at the Q1 gate and turning it on. In this circuit, the MOSFET turn-on and off operations are inversely controlled. This circuit is helpful because the high-side MOSFET gate requires a voltage greater than that of the load voltage with reference to ground, which is difficult to generate by a microcontroller itself. However, with this circuit, using a bootstrapping capacitor and the low-side switch Q2, we are now able to

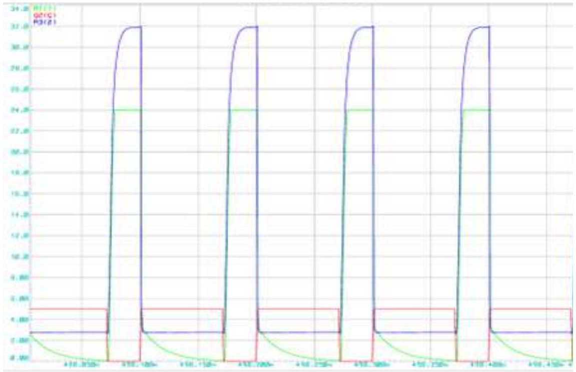

Fig. 15. The results of the MOSFET-gate drive circuit simulation in the Proteus-SPICE software are shown in the following traces: the red trace represents the gate pulse given to the Q2 switch, the green trace represents the voltage across the resistive load, and the blue trace represents the gate voltage of the high-side switch referenced to the ground

control the high-side switch using the pulse generated by the microcontroller itself.

In the plot, we can see that with a gate pulse of 5 volts given to the Q2 switch, we can inversely control, the high-side Q1 switch.

V. CONCULSION

Vehicle-to-Grid (V2G) technology and its effects on the electrical grid are summarised in this article. A non-isolated bi-directional buck-boost converter's gate drive and closed-loop control circuit architecture are covered in detail. Utilising MATLAB/Simulink, a simulation of a bi-directional buck-boost converter is carried out in buck mode, charging a lithium-ion battery to transfer power from the grid to an energy storage unit—in this case, the battery. The simulation findings are presented in the study, and they are mostly predicted. In addition, the PI controller has the ability to regulate the bi-directional controller for the buck mode. This demonstrates how expanding the study's scope and enhancing the grid's dependability can be accomplished by additional field research. One simulation model that is utilised is Proteus-SPICE.

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