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BIDIRECTIONAL ON-BOARD ELECTRIC VEHICLE CHARGER UISNG HIGH GAIN BOOST CONVERTER BASED ON ARTIFICIAL NEURAL NETWORK

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ABSTRACT: The main aim of this paper is Artificial Neural Network (ANN) controller based bidirectional on-board electric vehicle charger with high gain boost converter. In this paper A bidirectional converter is the primary requirement for an Electric Vehicle (EV) charger with advanced charging modes like V2G. The commonly used building modules of such a Bidirectional charger mainly consists of a buck converter and a high gain boost converter setup. This paper presents a bidirectional on-board single phase electric vehicle charger with a primary aim to achieve Vehicle to Grid (V2G) and Grid to Vehicle (G2V) applications. The battery charging and discharging is based on the state of charge of the battery. The ANN based on board electric vehicle charger gives more efficiency compared to existing PI controller. Simulation is carried out using MATLAB/SIMULINK software to validate bidirectional on-board charger capabilities with high gain boost converter.

Keywords: Artificial Neural Network (ANN), Electric Vehicle (EV), Vehicle to Grid (V2G), Grid to Vehicle (G2V)

I.INTRODUCTION

It is widely believed that EVs will eventually replace conventional gas-powered vehicles. With the goal of increasing the usage of EVs and decreasing India's long-term dependency on imported fossil fuels, the Indian government has developed a number of projects to support research into EVs. More often than not, the purpose of these research is to enhance EV technology in some manner, whether it by making it more trustworthy, user-friendly, or cost-effective. The V2G technology is being studied extensively because of its importance in this context. Plugging electric vehicles into the grid allows them to act as both loads and generators. Various variables, including charging habits, charging settings, and charging patterns, add to the load that PEVs present [1]. V2G and G2V refer to the two major modes of operation. In Grid to Vehicle (G2V) mode, automobiles work as traditional loads, but in Vehicle-to-Grid (V2G) mode, energy is returned to the grid. Vehicle-to-Home (V2H) is a subset of V2G that functions like a UPS in a house [1]. Depending on their power requirements, electric car chargers may be either on-board or external. When power consumption is modest, a single-phase on-board charger is often sufficient (3-6 kW). A standard one-way charger can charge a vehicle's battery since it generates the appropriate voltage and current waveforms. To the contrary, a sophisticated charger can carry out a variety of functions that are helpful to the owner of an electric vehicle.

The V2G-specific high-tech chargers may accomplish jobs like 1) voltage support, 2) reactive power compensation, 3) harmonic filtering, 4) power factor control, 5) load balancing, and 6) peak shaving. The charger's ability to give energy feedback functionality is essential for the EV battery to serve as a UPS in the event of a power loss [2]. While internal combustion engines were the norm for transportation for over a century, there has been a dramatic transition away from them in recent years. As fossil fuel sources decline, more and more governments are investing in the technologies necessary to make electric cars. This pattern is seen in both newly-industrializing and more-established states. As far as environmental impact goes, EVs are the way to go in the long run [6]. The current peak load demands may be

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mitigated with the use of vehicle-to-grid (V2G) technology. When connected to the power grid, EVs may act as mobile power stations, taking in and releasing juice as required [6]. This opens the possibility for electric automobiles to profit from the utility networks by utilising reserved power. As a possible charging solution for electric cars, bidirectional converter topologies have garnered a considerable lot of research. You may categorise them as either exterior (or "outboard") or internal (or "built-in") bi-directional chargers. Two-stage topologies, including an AC-DC rectifier/inverter and a DC-DC converter, are commonplace in bidirectional chargers seen in practise. Its components are often robust and strong, and they find use in areas like quick charging and discharging. Due to its power rating, size, cost, and noise [12], external bi-directional chargers are more suited to corporate load stations than residential locations. The built-in bidirectional chargers have a modest current since they are designed for domestic use and allow progressive charging [2].

II. PROPOSED BIDIRECTIONAL CONVERTER TOPOLOGY

Based on our findings, we recommend a network layout that streamlines communication between the grid and EV batteries. The only thing occurring is a series connection between the two systems. For voltage-to-current (V2G) operation, a high gain booster, inverter, and utility grid are used; for grid-to-voltage (G2V) operation, an AC-to-DC (buck) converter, battery, and utility grid are used. The precise operation of G2V and V2G systems is the subject of this research. This study describes a protocol for two-way data exchange between the battery of an electric car and the general power grid. For G2V functioning, the first system cascades a direct current to voltage (DC-DC buck converter) and an alternating current to direct current (AC-DC) converter from the utility to a battery. The second method involves cascading power from the battery to the inverter and the utility. An analysis of G2V and V2G capabilities in a non-isolated charger topology that complies with the design requirements is the primary goal of this study.

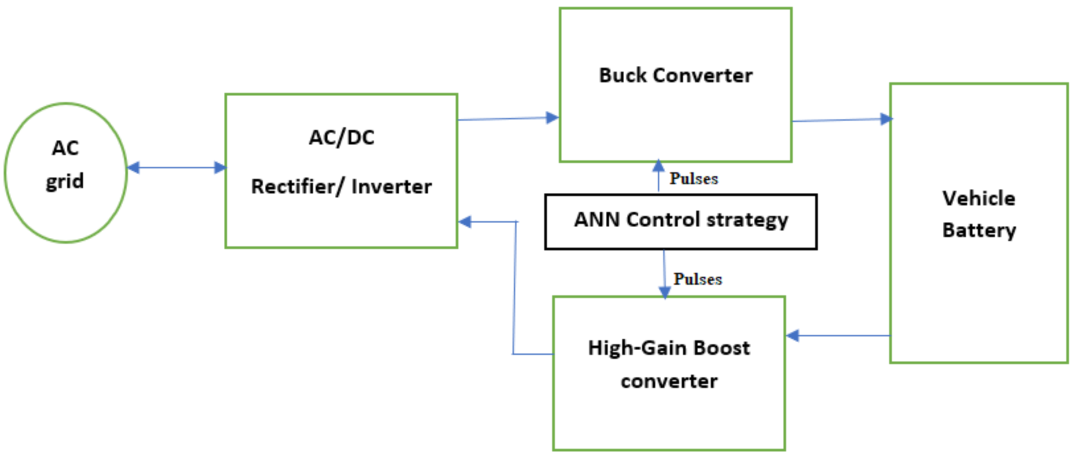

Fig .1 Block diagram of the Bidirectional PEV's Battery System

Since non-disengaged converter types often need to provide a large voltage gain, operating at a high duty ratio is not unusual. This causes a significant amount of conduction loss because of the high output requirements. A high gain boost converter is utilised instead of a standard boost converter to reduce losses and increase system efficiency [9]. Two diodes, two capacitors, and a linked inductor make up the high gain boost converter. The main advantage of the high gain boost converter design is the elimination of the transformer, which permits high voltage gain while yet maintaining a fast-running cycle.

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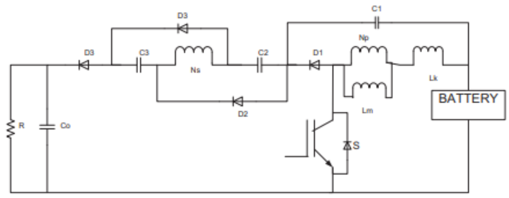

Fig .2 Detailed Circuit Diagram of a High-Gain Boost Converter

The state-of-charge (SOC) of the battery must be continually monitored for the bidirectional battery architecture to work (SOC). Design success depends on specifying the buck and high gain boost converter's operating circumstances. If the procedures are not performed in the correct order, the G2V or V2G conversion will fail. An SOC is required for this topology to work. SoC monitoring may be used to check a battery's health while charging and discharging [4, 7]. Due to the use of two distinct converter topologies, careful cascading of the whole system is essential.

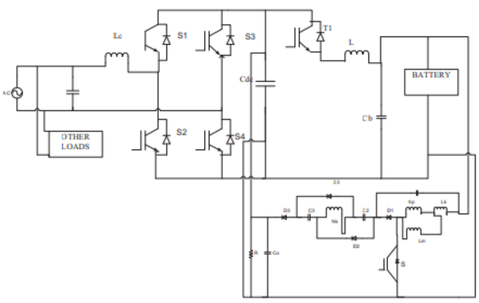

Fig. 3 Topology of a Bidirectional Converter (Buck and cascaded high gain boost converter topology)

III. DESIGN OF CONVERTERS

BUCK CONVERTER DESIGN:

One of the most primary non-isolated converter topologies is the buck converter layout. With the existence of an IC controlled active switch along with a rectifier and filtering element, the buck converter provides great simplified solution for in-order to carry out fruitful and highly productive power dissemination all through the application. The buck converter is used in the bidirectional converter topology in-order to decrease the rectified output voltage of 230V to 48V which is required by the vehicle battery

$$D = \frac{V_O}{V_S} \quad (1)$$

$$L = \frac{R(1-D)}{2F_S} \quad (2)$$

$$C = \frac{(1-D)V_O}{8L\Delta V_O F_S^2} \quad (3)$$

HIGH GAIN BOOST CONVERTER DESIGN:

The high gain boost converter is a high efficiency, high voltage steps up type of converter. It also consists of a coupled inductor. The high voltage is acquired through two additional pairs of capacitor and diodes, where in the capacitors are charged and discharged through the coupled inductor [5]. The converter consists of a power switch S, clamp diode D1 and capacitor C1, blocking diodes D2 and D3 along with blocking capacitors C2 and C3, output capacitor Co and diode Do and coupled inductors. Ideal setting is considered for the power MOSFET and the diodes. The high gain boost converter is used at the time of V2G operation [11]. The vehicle battery voltage of 48V is boosted to the required grid voltage of 230V. The required system parameters of the high gain boost converter are acquired through the following calculations [5].

$$V_s = V_o(1 - D) \quad (4)$$

$$L = \frac{D(1-D)^2 R}{2F_S} \quad (5)$$

$$Co = \frac{I_O(1-D)V_O - V_S(2+nD)}{2V_O f V_S} \quad (6)$$

$$C1 \frac{2\,DV_O}{(1-D)\Delta V_{C1} Rf} \quad (7)$$

$$C2 = \frac{V_o}{2R\Delta V_{c1} f} \quad (8)$$

$$C3 = \frac{DV_o}{R\Delta V_{c1} f} \quad (9)$$

$$Lm = \frac{D(1-D)^{2R}}{2(n+2)(2+nD)f} \quad (10)$$

WORKING ALGORITHM FOR BATTERY

During charging and draining, the battery's charge level is strictly maintained. The SOC is compared to a user-set value to control the battery's charging or discharging. The SOC balancing algorithm, also known as the battery operating algorithm, is responsible for this. You must have at least some charges left in the battery before you can use the bidirectional charger. If the battery's state of charge (SOC) falls below a certain point, the charger will switch to grid-to-vehicle (G2V) mode and send energy back to the grid, but otherwise, the battery will drain via the charger.

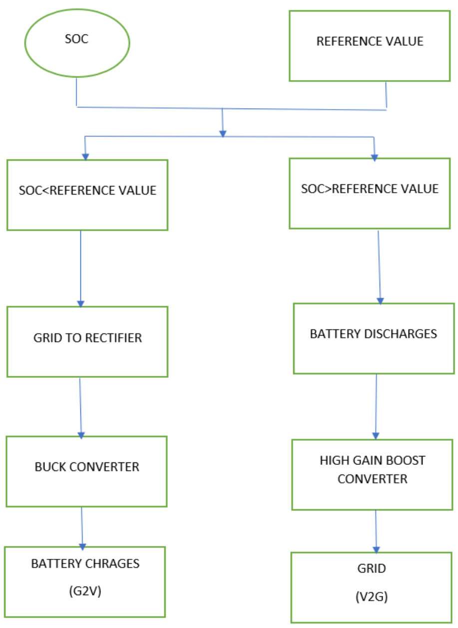

Fig .4 The charging and discharging curves for the battery

A converter topology is used to charge or drain the battery to a predetermined value relative to some other parameter. The battery will discharge to the grid via the high gain boost converter if the state of charge (SOC) is above the setpoint. A buck converter will begin drawing power from the utility grid to charge the battery when the battery's state-of-charge (SOC) drops below a predetermined threshold.

IV. ARTIFICIAL NEURAL NETWORK CONTROLLER

The offline trained Neural Network (NN) controller as shown in fig (5).

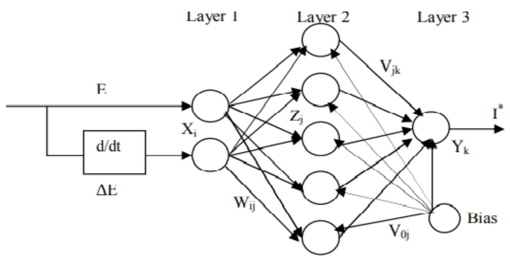

Fig .5 A Neural Network Diagram of the Control System

This makes NNs ideally suited for the prediction, control, and optimization of industrial processes, as the connective weights of the NN based control are trained using error (E) and the rate of change of error (E) to minimise the tracking error between the reference (V*) and actual current (I) of the controller. Two neurons are inputs (Xi), one is outputs (Ky), and the remaining five are hidden (Xi+1) (Zj). The connection weights Wij, Vjk between neurons in one layer and neurons in the next layer impact the training performance of the Neural network controller. There is a tan sigmoid activation function in the hidden layer, and a purlin activation function in the output layer. The information used to train our neural network originally came from traditional controllers

V. SIMULATION RESULTS

SYSTEM SPECIFICATIONS

Parameters	Values
Grid Voltage	230V
Vehicle Battery Voltage	48V
Switching Frequency	50KHz
DC Link Capacitance	7.4μF

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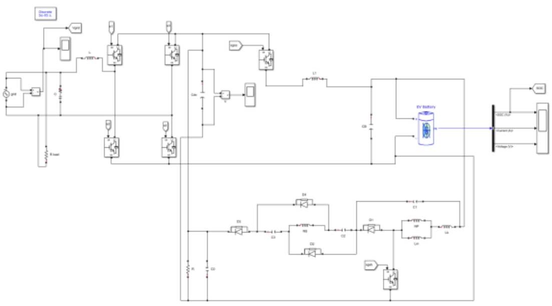

Figure.6 MATLAB/SIMULINK depicts the construction of a bidirectional converter (Buck and cascaded high gain boost converter topology)

A) EXISTING RESULTS

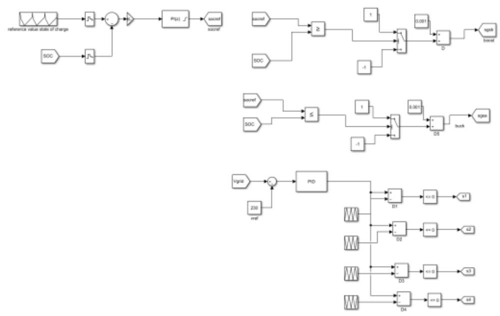

Figure 7 depicts a control system implemented using a PI controller.

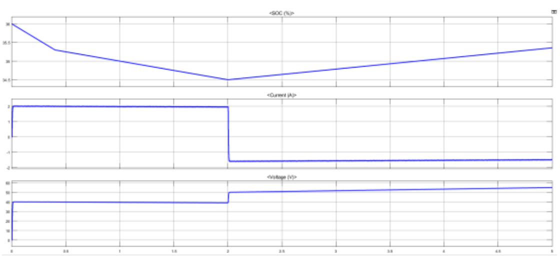

Figure.8 shows charging and discharging statistics for voltage, current, and state of charge for a battery.

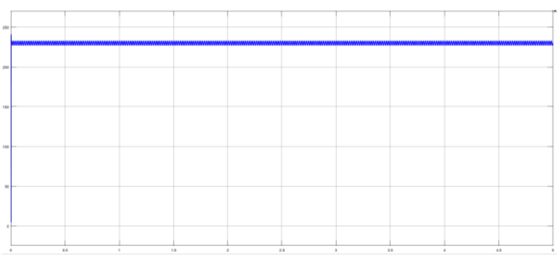

Figure 9: DC Link Voltage

B) EXTENSION RESULTS WITH NEURAL NETWORK CONTROLLER

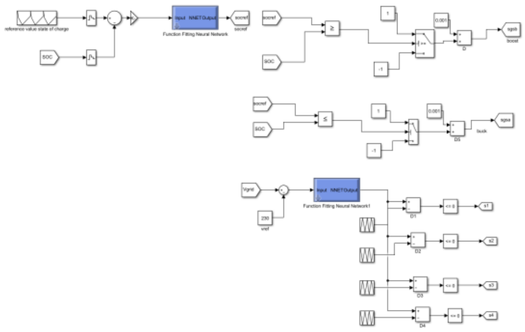

Fig .10 Control system using an artificial neural network controller.

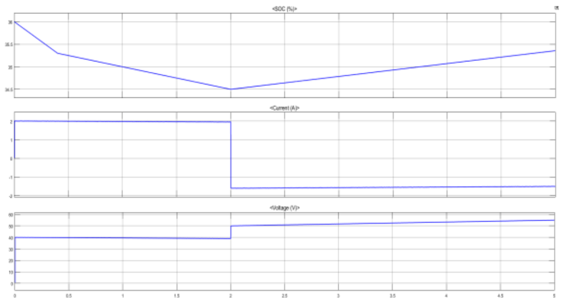

Fig. 11 During charging and discharging, it displays the battery's current, voltage, and SOC.

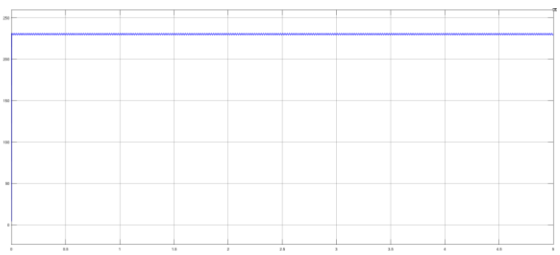

Figure.12: DC Link Voltage.

CONCLUSION

The electric vehicle's dual role as energy provider and consumer presents exciting opportunities for utilities. G2V and V2G are the two possible charging methods. The charger incorporates a bidirectional AC-DC charger and a cascading DC-DC converter to generate the required voltage. Instead of a boost converter, as is used in the V2G mode, a buck converter is used in the G2V mode of the integrated DC-DC converter. With a 48V battery model and a DC connection voltage of 230V, the MATLAB simulation of a bidirectional electric vehicle charger for a V2G application runs well. It is clear from the simulation graphs that the converter functions correctly in both the G2V and V2G modes of operation. Batteries that have been charged or discharged according to the instructions will function normally. In addition, a consistent dc link voltage of 230V is maintained throughout the charging and discharging processes. When the battery's state of charge (SOC) is higher than the reference value, it discharges and delivers voltage back to the grid; otherwise, it charges and draws power from the grid. The artificial neural network (ANN) driven electric vehicle (EV) system on board causes far less waves than the current technology. In comparison to existing bidirectional EV chargers, which only provide G2V or V2G modes of operation, the suggested ANN-based converter holds its own.

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