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A BI-DIRECTIONAL EV CHARGER FOR GRID CONNECTED ELECTRIC VEHICLE APPLICATIONS

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Abstract

This paper proposes a new electrolytic capacitor-less bi-directional EV charger for grid connected electric vehicle applications. When electric vehicles are connected to the power grid for charging, they become grid able EVs (GEVs). This paper investigates and discusses the challenges of GEVs for vehicle-to-grid (V2G), vehicle-to-home (V2H) and grid-to-vehicle (G2V) operations. A bi-directional DC-DC converter is connected in series with the grid, which minimizes the switching losses and improves the efficiency of the system. Simulation analysis and hardware implementation is performed, executing the three modes of operation of the proposed bidirectional EV charger.

***Key Words*:** Bidirectional EV charger; grid able electric vehicles (GEVs); vehicle to grid (V2G); vehicle to home (V2H); grid to vehicle (G2V).

1

1 INTRODUCTION

The usage of fossil fuels emits greenhouse gases, which leads to environmental pollution. Hence, considering the secured and healthy life of human, electric vehicles (EVs) has been employed. Here, a bidirectional, capacitor less EV charger is proposed for electrical vehicle applications like V2G, V2H and G2V.

The automobile industry demands for higher fuel economy and vehicular power system, which integrates power electronic intensive solution [1]. For reducing emissions and improving fuel economy, hybrid and plug-in hybrid where implemented [2]. But there are economic losses in this system. The charging and discharging is done by bi-directional DC-DC converter [3] [8]. But, here the gain value is reduced. The communication between the EV and an aggregator (V2G) has been performed [5], but it is unidirectional. Implementation of V2G application, for a high frequency regulation power generation system by using the hybrid electric vehicle is more reliable and economical by using optimization techniques. But it difficult to implement considering the practical constrains and mobility systems [4] [6].

The V2G and V2H applications achieved by bi-directional charger has been implemented for plug in hybrid electric vehicles. Because of this hybrid battery charging system, there is increase in the power grid harmonics [12]. However the concept of V2G, V2H and G2V technologies were explained [9]. In our proposed work, three applications: V2G, V2H and G2V were implemented.

For residential power demand, the grid should have some backup power, which is done by the PEV model [7]. For plug-in and hybrid electric vehicles, the charging and discharging categories of off board and on board types in unidirectional and bi-directional power flow is analysed [10] [16]. The operation of these systems depends upon the battery levels. The on board topologies were used for the better efficiency of the battery, rather than conventional control techniques [11]. Implementation of bi directional power flow between grid to electric vehicle battery by using the dual active bridge conversion with a bi directional topology improves the power quality, active and reactive power control [13] [17]. It also increases the cost for better efficiency. The efficiency of battery and power grid is improved by using different type of technologies like distribution system and utility interfaces. But due to implementation of advanced infrastructure for the circuit makes it uneconomical [14] [15].

Two modes of operation has been performed: Vehicle to Home (V2H) and Grid to Vehicle (G2V) [18]. Here, a resonant tank has been employed for the implementation of these modes of operations. The tank circuit will experience the resonance condition when the capacitive reactance is equal to inductive reactance. By removing the resonant tank and decreasing the components to get a better efficiency for a system a new technology is implemented in this proposed system.

2 PROPOSED BIDIRECTIONAL EV CHARGER

The proposed bi-directional, capacitor less EV charger consists of grid type capacitor, resonant bi-directional converter, grid selector, load and battery. The grid type capacitor acts like a grid which stores power and also supplies power whenever needed. It is connected to a bi-directional DC-DC converter, which reduces the switching losses, thereby improves the efficiency of the proposed system. The grid selector plays an important role in the proposed system. The grid selector performs three modes of operation, like Vehicle to Grid (V2G), Vehicle to Home (V2H) and Grid to Vehicle (G2V). It acts like a switch and performs the operations of various modes depending on the power requirement of various components. The home appliances is considered as load. The use of the battery is to store energy and supply power to the home appliances when needed. The block diagram of the proposed EV charger is shown in fig. 1.

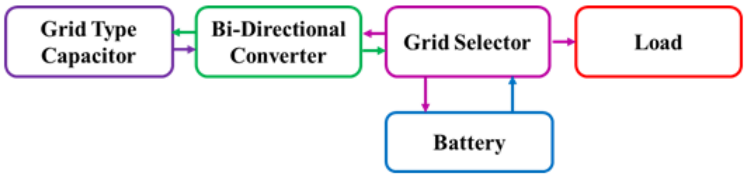

Fig. 1. Block diagram of proposed EV charger

The proposed bi - directional EV charger is categorized in to three modes of operation: Vehicle to Grid (V2G), Vehicle to Home (V2H) and Grid to Vehicle (G2V). In V2G and V2H mode, the battery supplies grid and load and in G2V mode, the grid supplies load. The simulation analysis and the experimental results of hardware prototype for the three modes of the proposed system is discussed in the fore coming sections.

3 SIMULATION ANALYSIS

Simulation analysis of the three modes of operation is done by using matlab software. The three main parts of the proposed EV charger, grid type capacitor, battery and the load are connected to the simulation circuit, as shown in fig.2. The scope is connected at each terminal to view the output of each component. The charging and discharging nature of grid type capacitor, battery and load are displayed in the scope.

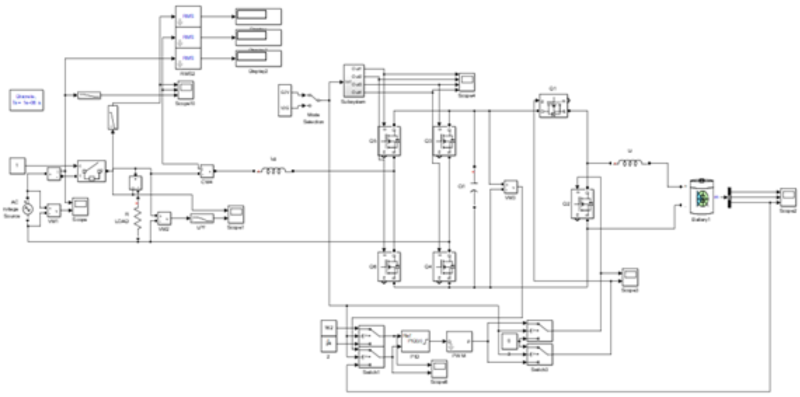

Fig. 2. Simulation circuit for the proposed EV charger

A. Vehicle to Grid (V2G) mode

In this mode, the battery supplies power to grid as well as load. So that battery gets discharged whereas, the load and the grid get charged automatically. The discharging nature of the battery is shown in fig. 3(a). When the battery gets discharge the load as well the grid has to be charged as shown in fig. 3(b) and fig. 3(c). The load and grid obtains a maximum voltage of 230V.

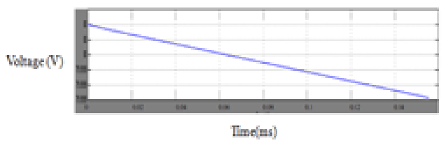

Fig. 3(a). Discharging of battery

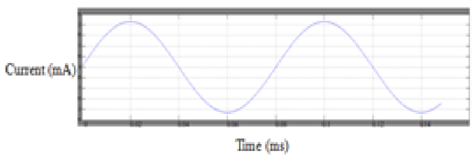

Fig. 3(b). Charging of load

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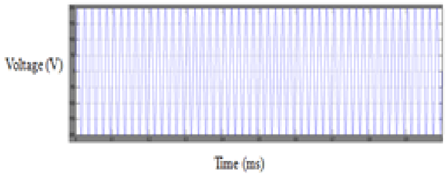

Fig. 3(c). Charging of grid

B. Vehicle to Home (V2H) mode

In this mode, the battery supplies power to grid as well as load. But here the grid is closed by using a switch, so that the entire power goes to load. The discharging of battery and the charging of load is shown in fig. 4(a) and fig. 4(b).

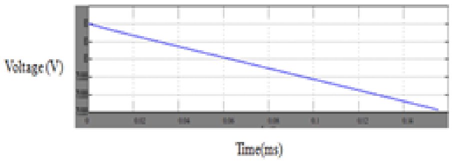

Fig. 4(a). Discharging of battery

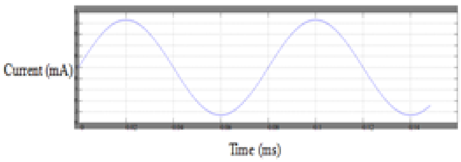

Fig. 4(b). Charging of load

C. Grid to Vehicle (G2V) mode

In this mode, grid starts discharging, as it is giving supply to the battery and load. Hence the battery and the load starts charging as shown in fig. 5(a) and fig. 5(b). The discharging nature of grid is shown in fig. 5(c).

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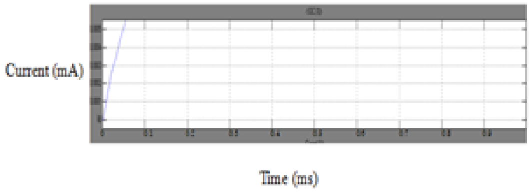

Fig. 5(a). Charging of battery

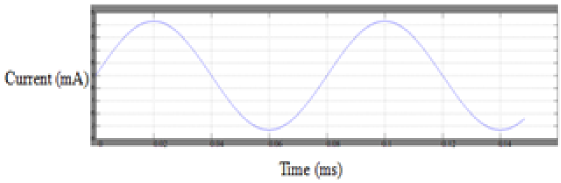

Fig. 5(b). Charging of load

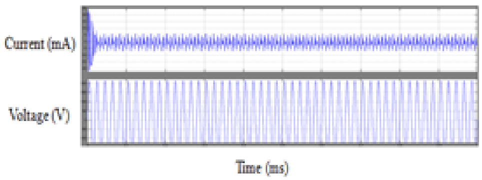

Fig. 5(c). Discharging of grid

4 HARDWARE IMPLEMENTATION

The proposed EV charger consists of three main parts, namely grid type capacitor, battery and the load. The Hardware setup of three modes of operations: V2G, V2H and G2V are shown in fig. 6(a), 6(b), 6(c) respectively. In first and second mode of operations, the battery is discharging whereas, the load and the grid capacitor is charging. The charging of load is represented by the glowing of LED bulb. When coming to third mode of operation (G2V), the grid capacitor starts discharging as it charges the battery and the load.

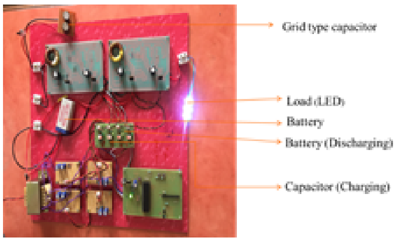

Fig. 6(a). Vehicle to Grid

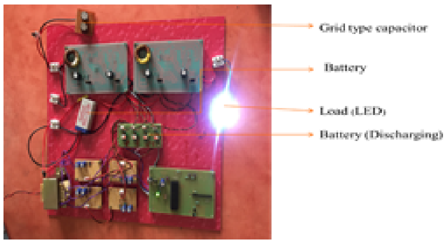

Fig. 6(b). Vehicle to Home

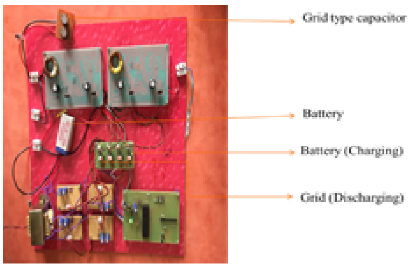

Fig. 6(c). Grid to Vehicle

5 CONCLUSION

This paper analyses thoroughly the operations of a bi-directional EV charger for grid connected electric vehicle applications. The framework of the paper is vehicle to grid (V2G), vehicle to home

(V2H) and grid to vehicle (G2V) and modes of operations. The great challenges behind the three modes of operations is discussed clearly. Experimental results for both simulation and hardware implementations are obtained with improved efficiency.

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