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Analysis of Dual Active Bridge Converter for EV Charging Applications

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ABSTRACT

The electric vehicle becomes more popular in the world wide and plays an imperative role in transport sector because of pollution free environment. So, there is a need to develop the required electric vehicles (EV) infrastructure particularly the EV charging satation as per the requirement by mitigating its challenges and also, the converters plays significant role in EV charging station. In this paper, a converter namely dual active bridge (DAB) converter has been utilized to charge the energy storage device in the EV under constant current mode and constant voltage mode in MATLAB/Simulink environment. The results show the effectiveness of converter scheme for EV charging applications in both modes of operation.

KEYWORDS: Electric Vehicles, constant current, constant voltage, dual active bridge

1. INTRODUCTION

The Electric vehicle prospective has largely been tinted in providing ancillary services in a micro grid, such as grid reserve & regulation support. The behaviors of EV charging raise critical concerns for both the utilities and EV owners. The impact of EV charging uncertainties has been discussed [1]. A 2-kW SiC-based DAB converter including a variable inductor for different operation condition has been discussed [2]. The compensation topologies and control schemes for dynamic wireless power transfer (DWPT) with respect to electric vehicle battery size requirements has been explained [3]. In ref[4], a universal power flow model for the dual active bridge based dc–dc converters with phase-shift modulation is presented. A fault-tolerant scheme for open transistor faults applied to 3-phase dual active bridge converters using different transformers has been presented [5-7]. The state-of-the-art technology, standards for fast charging, power quality issues, IEEE and IEC PQ standards, and mitigation measures are reviewed [8]. An Intelligent Charging Scheduling Algorithm (ICSA) with EVs scheduling as an optimization problem is proposed [9]. A modular equalization system using dual phase-shift controlled dual active bridge converters has been discussed with direct cell-to-cell equalization [10]. A comprehensive study on the feasibility of integrating EVs into the existing distribution system using the water cycle algorithm has been presented [11].

The charging management of electric vehicles that considers time anxieties and different behaviors of EV customers along with different converter configurations has been discussed [12-16]. A Report on the EV charging standardization framework to bring homogeneity in Indian market has been presented [17]. In this paper, the dual active bridge converter performance has been analyzed for constant current mode and constant voltage mode operations of EV charging applications using MATLAB/Simulink. The results show the effectiveness of converter scheme for EV charging applications in both modes of operation.

STRUCTURE OF PAPER

The paper is organized as follows: In Section I, the introduction of the paper is provided along with the structure, important terms, objectives and overall description. In Section II we discuss system configuration and operation. In Section III we have the complete information about EV charging. Section IV shares information about the results and analysis. Section V tells us about the conclusions of the paper with references.

2. SYSTEM CONFIGURATION AND OPERATION

The schematic diagram of the grid connected dual active bridge converter is shown in Fig.1. It consists of voltage source converter (VSC) connected to the grid. The function of the VSC is to supply the power required to the system by maintaining the constant DC-link voltage. In the next stage, H-bridge present in the primary side of the high frequency transformer converter converts DC-link voltage 'v_{gd}' to a high frequency AC voltage. The galvanic isolation between the grid side converters and the electric vehicle is obtained by the high frequency transformer. Finally the diode bridge converter converters high frequency AC to DC voltage across the energy storage device of the EV. The control algorithm used for the entire system is displayed in Fig. 2. The controller1 generates maximum value of the current that need from the grid to maintain the reference voltage 'v_{gd}'. Later the controller2 tracks the grid current in synchronized with grid voltage using Phase Locked Loop (PLL). In the DAB converter the reference state of charging (SoC) is maintained by determining the required charging current of the energy storage using controller3. Later Controller4 will control the energy storage current using internal phase shift angle in the converter

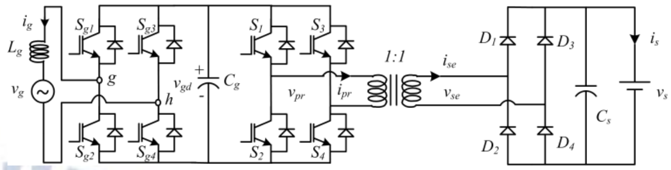

FIG.1: SCHEMATIC DIAGRAM OF CONVERTER CONFIGURATION

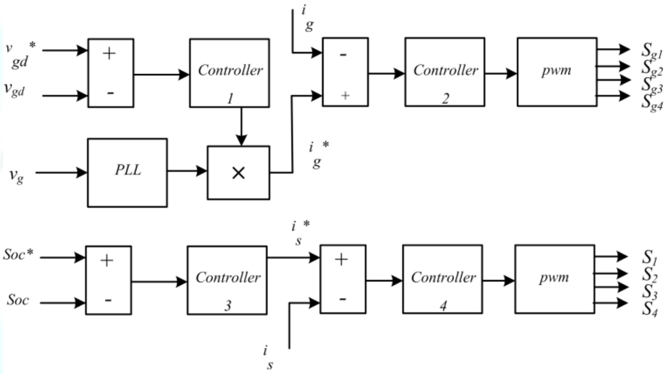

Fig.2: Schematic diagram of converter control circuit

3. EV CHARGING

The general block diagram of an electric vehicle charging system is shown in Fig.3. The charging system needs to maintain the required voltage level for safe charging of the batteries inside the vehicle.

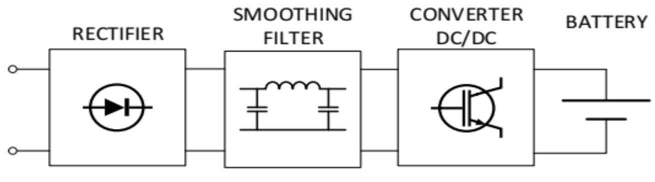

Fig.3: Block diagram of an electric vehicle charging system

It mainly consists of a rectifier and a DC/DC converter. The rectifier converts the alternating current into a direct current, which can be used to charge the battery in the electric car. In between the rectifier and battery, the DC/DC converter helps for adjusting the SoC of the battery and controls the charging process. The grid-to-vehicle (G2V) and vehicle-to-grid (V2G) are two charging configurations. In G2V configuration, unidirectional flow of electricity between the mains and battery vehicle, whereas bidirectional flow of electricity in V2G charging configuration. The V2G charging configuration is more popular than G2V.

4. RESULTS AND ANALYSIS

In this section, the performance analysis of the converter for EV charging has been carried out in MATLAB/Simulink environment. The simulation study parameters are listed in Table-1. The initial state of charge (SoC) of the battery is considered to be 98% of its full capacity for the demonstration purpose. The performance parameters such as battery voltage, current and power flowing in to the battery is displayed in Fig.4. From time 0 to 2.5 seconds battery is operating under constant current (CC) mode of operation. Since, the battery charging current is limited to 10A the controller is able to maintain the same. During this mode SoC of the battery is reached to 100% at 2.5 seconds and the charging power is 3.6kW. After 2.5 seconds, since it reaches to the 100% SoC the controller is able to maintain the constant SoC by drawing only 0.2A of current to compensate the loss in the battery due to its internal resistance. Since the battery voltage during period is almost constant it is termed as constant voltage (CV) mode of operation. The power drawn during this mode is almost negligible when compared to the CC mode of charging.

Table 1 : Simulation Parameters

Parameter	Value
Grid voltage	230 V, 50 Hz
Battery	6*48 V, 120 Ah
Turns ration of transformer	1:1
DC-link voltage	400V
L_g	3 mH
C_{DC}	2200 μF
C_b	2200 μF
Switching Frequncy	20 kHz

Similarly Fig.5 depicts waveforms of grid voltage, current and DC–link voltage of the front end converter during the CC and CV mode of operations. From 0 to 2.5 seconds under CC mode, the grid current is in phase with the grid voltage with a magnitude of almost 20A. The zoomed portion of the same is displayed in Fig.6. During CV mode the magnitude of the supply current drawn from the grid is about 0.8A. The zoomed portion of the grid voltage, current and DC-link voltage during this mode is shown in Fig.7. In both CC and CV modes the front end converter is strictly maintain the required DC-link voltage for the system which is about 400V.

The variation in the high frequency transformer parameters during the operation such as primary voltage & current, secondary voltage & current were shown in Fig.8 and Fig.9 shows the zoomed portion of the same in CC mode of operation. It can be observed that the internal phase shift of the primary converter is adjusted such that it can maintain the CC. Similarly Fig.10 shows zoomed portion of the transformer voltage and currents during CV operation mode. Since the charging power of the battery is very less the internal phase shift is controlled such that to maintain the same.

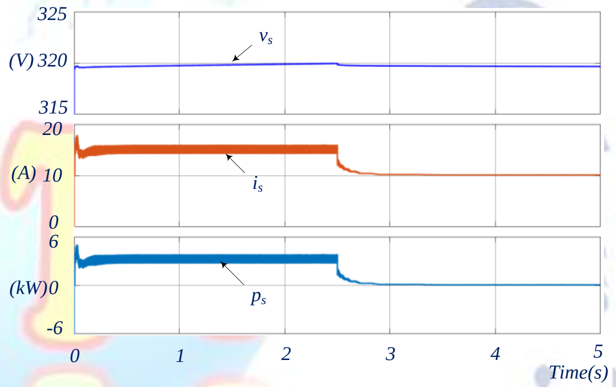

Fig.4: Voltage, charging current and power flowing in to the battery of the EV.

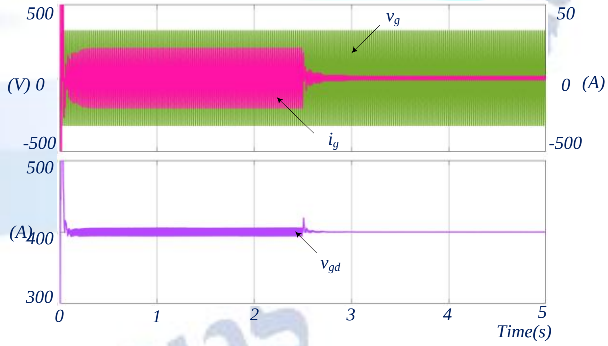

Fig.5: Grid voltage, current and DC-link voltage

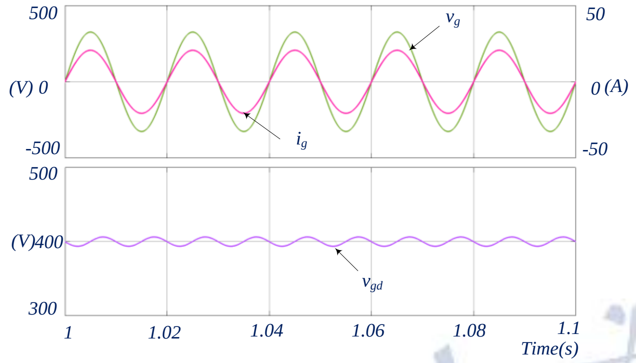

Fig.6: Grid voltage, current and DC-link voltage under CC operation mode.

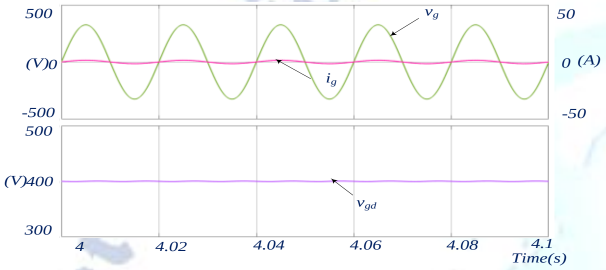

Fig.7: Grid voltage, current and DC-link voltage under CV operation mode.

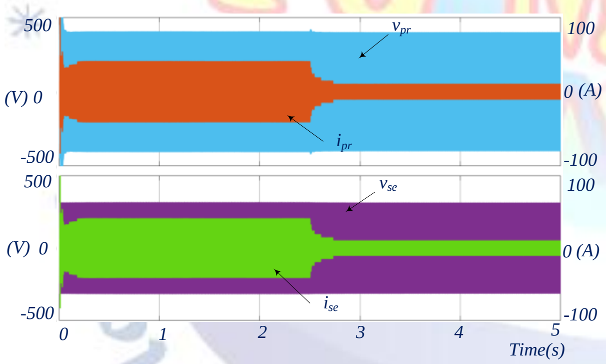

Fig.8: High frequency transformer primary voltage & current, secondary voltage & current

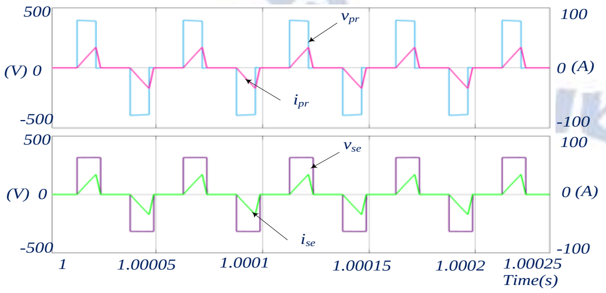

Fig.9: High frequency transformer primary voltage & current, secondary voltage & current under CC operation mode.

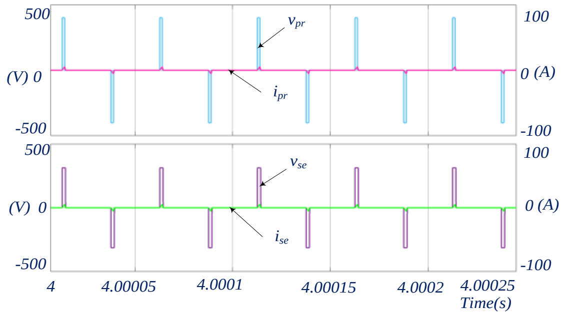

Fig.10: High frequency transformer primary voltage & current, secondary voltage & current under CV operation mode.

5. CONCLUSION

In this paper, the dual active bridge (DAB) converter performance analysis has been carried out for EV charging applications. The simulation results present in this paper shows the best performance under constant voltage and current modes of charging of the energy storage present in the EV. The power supplied to the energy storage under CC mode of operation is achieved to a level of 3.6kW which is best suitable for residential and commercial EV charging applications. During constant voltage mode the controller is able to maintain the constant SoC by drawing negligible amount of current 0.2A. The power drawn during CV mode is almost negligible when compared to the CC mode of charging. Finally, the simulation results shows the effectiveness of the converter scheme for EV charging applications in both modes of operation and switching to electric vehicles is beneficial in the long run due to clean energy which leads to less environmental effects.

Conflict of interest statement

Authors declare that they do not have any conflict of interest.

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