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Grid to Vehicle and Vehicle to grid Bidirectional Power Transfer Systems for EV Application

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ABSTRACT: Wireless Power Transfer (WPT) for Electric Vehicle (EV) battery charging application is one of the key upcoming technologies. The possibility of using EVs to transfer power back to the grid, utilizing the concept of Bidirectional Wireless Power Transfer (BD-WPT) is extensively being explored. The effect of integration of EV on grid is also of concern. This paper presents analysis of complete grid integrated BD-WPT system for controlling power transfer between grid and EV battery, along-with ensuring Unity Power Factor (UPF) at grid side. Mathematical model of each component in the system is presented which is then used to design vehicle and grid side controllers for achieving desired output. Concepts stated analytically are validated by simulation in MATLAB (Simulink)

KEYWORDS: BD-WPT, UPF, EV

I. INTRODUCTION

The increasing global concern over depletion of fossil fuel reserves and their adverse effects on the environments have resulted in fast development in technologies like renewable energy generation and EVs. Conductive charging has been long introduced but is still not preferred due to tripping hazards, leakage from old cracked cables (particularly in cold zones), risk of electric shock etc. Major drawback of present EVs is the power storage technology, usually battery, which has very unsatisfactory performance. Long charging time of EV batteries is the main reason for its low popularity among consumers. Introduction of wireless power transfer for EV battery charging is thus being considered as a probable solution for aforementioned issues in conductive charging. Wireless charging technique provides several advantages like galvanic isolation, convenient and safe usage in addition to low maintenance due to no physical contacts or moving parts. Also, the battery capacity of EVs with wireless charging could be reduced to 20% or less compared to EVs with conductive charging. Most of the developments in WPT technology have mainly been in applications requiring unidirectional power transfer. In recent years, BD-WPT systems have become popular for implementing the concept of Vehicle to Grid (V2G) for grid integration of EVs. To reduce the effects caused due to intermittent nature of renewable energy systems and facilitate dynamic demand management, V2G concept can be used as cost-effective alternate energy storage unit.

In this work, a complete system depicting V2G and G2V concept for controlling desired power transfer between grid and EV battery, along-with ensuring unity power factor at grid side has been analyzed and simulated in MATLAB

II. WORKING OF PROPOSED SYSTEM

A block diagram broadly describing the elements of a bidirectional wireless power transfer system is shown in Fig. 1. It consists of two sides: primary and secondary. Primary side is connected to the utility grid via a dc link and is usually embedded under the road in places like traffic signals, bus stops, vehicle charging stations etc. The secondary side is connected with EV battery and is placed at the bottom of electric vehicle. As can be seen in Fig. 1, both sides consist of coupling coils, high frequency (HF) converters, compensation circuit and dedicated controllers. When power flows from grid to EV battery (forward direction), primary converter acts as an inverter (DC/AC) and secondary

converter acts as a controlled rectifier (AC/DC). Similarly, when EV battery supplies power to the grid (reverse direction), the role of converters is reversed. As already mentioned, there are compensation networks on both primary and secondary sides.

This is the concept used by researchers to increase the power transfer efficiency in WPT system. Primary side resonance is used to reduce the Volt-Ampere (VA) rating of the power electronic converter and secondary side resonance to reduce VA rating of the coil [2]. Based on application, suitable converter topology, compensation technique and control technique are chosen. In this work, full bridge Voltage Source Converter (VSC) with LCL compensation topology at both primary and secondary sides will be analyzed. Following are the parameter considering while design the proposed system.

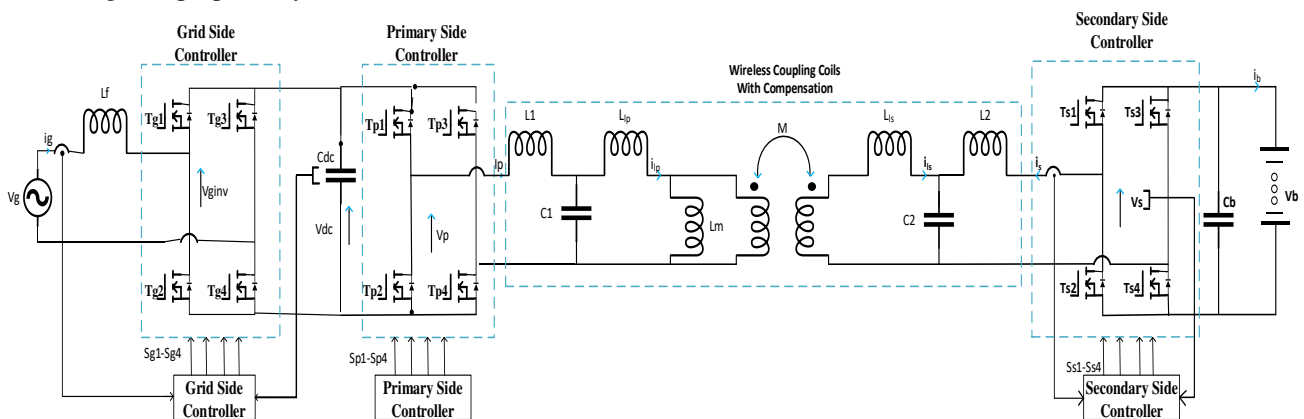


Fig-1 Grid Connected BD-WPT System

Wireless Power Transfer (WPT) for Electric Vehicle (EV) battery charging application is one of the key upcoming technologies. The possibility of using EVs to transfer power back to the grid, utilizing the concept of Bidirectional Wireless Power Transfer (BD-WPT) is extensively being explored. The effect of integration of EV on grid is also of concern. This paper presents analysis of complete grid integrated BD-WPT system for controlling power transfer between grid and EV battery, along-with ensuring Unity Power Factor (UPF) at grid side. Mathematical model of each component in the system is presented which is then used to design vehicle and grid side controllers for achieving desired output. Concepts stated analytically are validated by simulation in MATLAB (Simulink)

III. SIMULATION

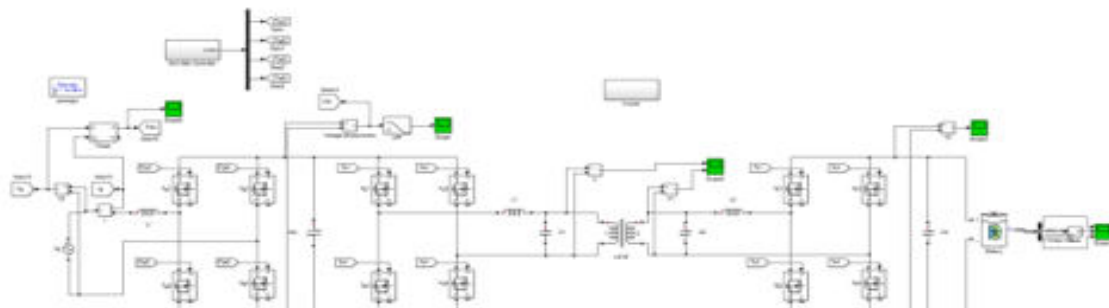


Fig 2. :Modelling of proposed test system



The above is the modelling of proposed circuit topology connected to single phase grid source, output is connected to EV battery. The below is the single phase fully controlled rectifier controller with feedback from DC link voltage.

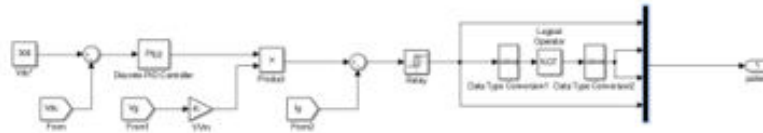


Fig3. : Grid side rectifier controller

The below is the phase shift PWM technique of the dual active bridge DC AC- AC DC- converter with grid power feedback selecting G2V or V2G modes. If Pref is positive the mode is G2V and if Pref is negative the mode is V2G.

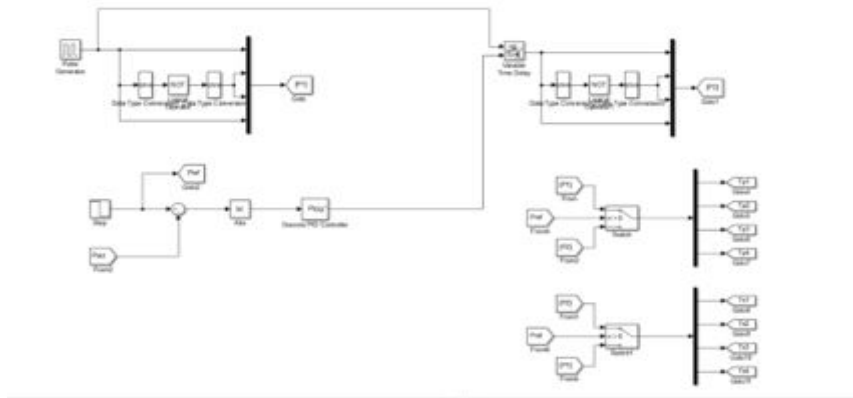


Fig.4: Dual active full bridge DC-DC converter controller

The below are the pulses generated for the dual active full bridge DC-DC converter from pulse shift PWM technique.

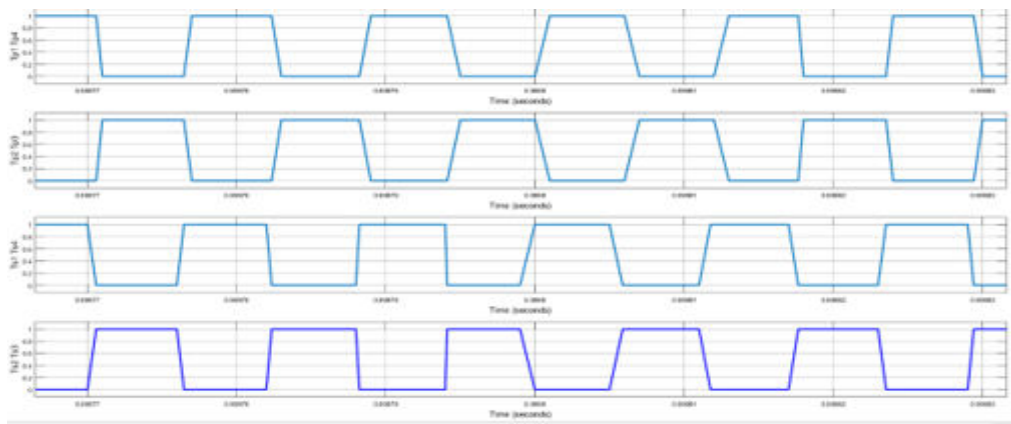


Fig.5 : Phase shift pulse of Dual active full bridge DC-DC converter



The below are the high frequency transformer primary and secondary voltages operating a very high frequency.

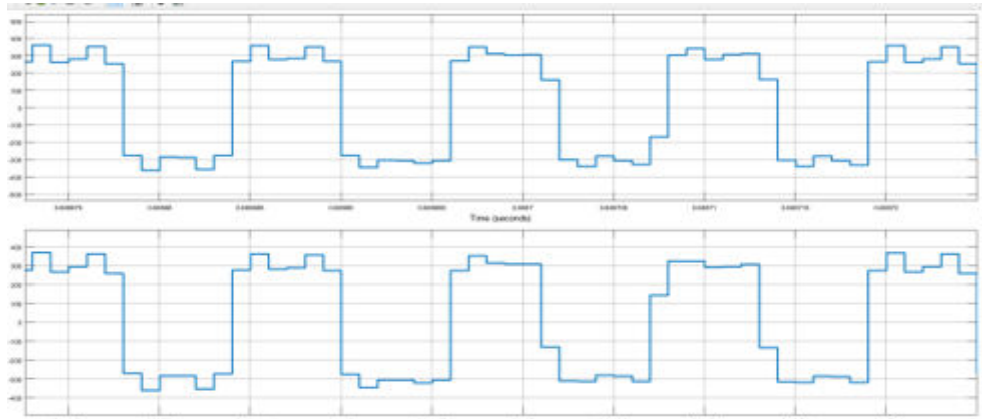


Fig.6: Primary and Secondary voltages of high frequency transformer

The simulation is run for 1 sec making the circuit to work in G2V mode from 0-0.5sec and in V2G mode from 0.5-1sec. The below is the direction of power of grid during both modes of operation.

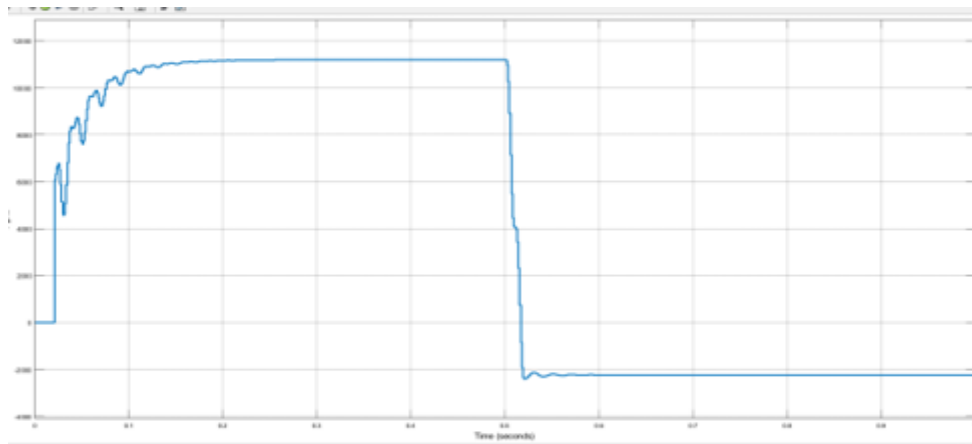


Fig7. : Grid active power

In any condition the DC link voltage is always at maintained at 300V and the graph is shown below.

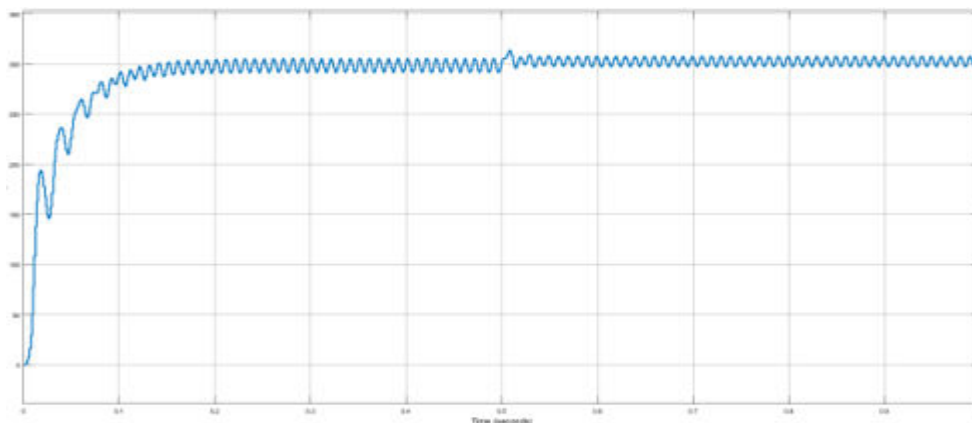


Fig.8: DC link voltage after controlled rectifier

For both the conditions the battery characteristics are shown below. As it can be seen the battery is charged from 0-0.5sec with raising rate of SOC and negative current. After 0.5sec the SOC is falling and the current is shift to positive direction showing discharging condition.

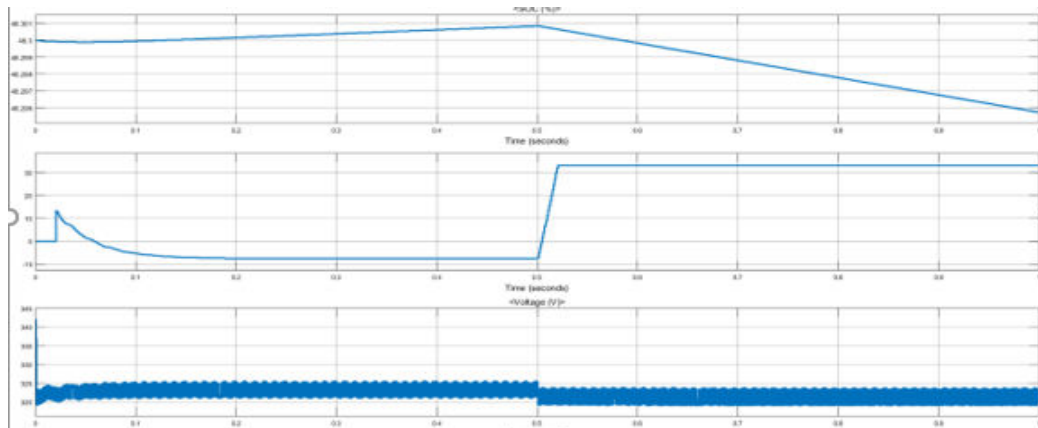


Fig.9: EV battery characteristics

IV. CONCLUSION

It can be observed that bidirectional power transfer for Grid side to Vehicle and Vehicle to battery had been implemented without any interruption. Simultaneously, simulation circuit is working in G2V mode for period of 0-0.5sec and then changing their mode to V2G by sensing the P_{ref} value given to its controller. Also, current and voltage waveforms had been shown in the result indicating the power transfer from in both the modes respectively. Also, it can be observed from the waveform of that the successful implementation of the flow of active power in the set parameters of both the modes is implemented. Furthermore, active power transfer settling time had been reduced and as well as distortions occurring in the output voltage had been reduced and had been brought nearly to a constant required output voltage using fuzzy controller as feedback control observed

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