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DESIGN AND ANALYSIS OF V2G AND G2V TECHNOLOGY IN ELECTRIC VEHICLES

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ABSTRACT

Electric Vehicle (EV) batteries can be utilized as potential energy storage devices in micro-grids. They can help in micro-grid energy management by storing energy when there is surplus (Grid-To-Vehicle, G2V) and supplying energy back to the grid (Vehicle-To-Grid, V2G) when there is demand for it. Proper infrastructure and control systems have to be developed in order to realize this concept. Architecture for implementing a V2G-G2V system in a micro-grid using level-3 fast charging of EVs is presented in this paper. A micro-grid test system is modelled which has a dc fast charging station for interfacing the EVs. Simulation studies are carried out to demonstrate V2G-G2V power transfer. Test results show active power regulation in the micro-grid by EV batteries through G2V-V2G modes of operation. The charging station design ensures minimal harmonic distortion of grid injected current and the controller gives good dynamic performance in terms of dc bus voltage stability.

INTRODUCTION

Electric vehicles include electric cars, Lorries, boats, motorcycles, and scooters. Typical vehicles are powered by fuels such as diesel, petrol and natural gas. It is observed that energy conversion efficiency of a fuel input in a conventional vehicle is only around 14%–30% depending on the distance covered. The remaining of the energy is either lost to engine or inefficiencies or it is used to power accessories. Therefore, there is immense potential to improve efficiency of fuel with advanced technologies. Hybrid and plug-in Electric vehicles are seen having potential for petroleum as well as carbon footprint reduction benefits. Increase in energy security, improvement in fuel economy, lower fuel costs, and reduced emissions (1). The PHEV vehicles use V2G technology. Under this technology the electricity can be sent back or feed into the Grid. The mass implementation of this technology will prove beneficial to not only the energy producers but also the vehicle owners. Electric engines have better efficiency when you compare them to a typical combustion engine, when the electricity used to charge vehicles comes from a CO2 emitting source, e.g. coal or gas fired powered plant, the overall net production of CO2 from an electric car is typically one third to one half that of the combustion vehicle. Plug-in electric vehicle (PEV) has a great potential of reducing the carbon footprint of transportation

Electric-drive vehicles, whether powered by batteries, fuel cells, or gasoline hybrids, have within them the energy source and power electronics capable of producing the 60 Hz AC electricity that powers our homes and offices. When connections are added to allow this electricity to flow from cars to power lines, we call it "vehicle to grid" power, or V2G. Cars pack a lot of power. One properly designed electric-drive vehicle can put out over 10kW, the average draw of 10 houses. The key to realizing economic value from V2G are gridintegrated vehicle controls to dispatch according to power system needs (2). Vehicle-to-grid can be used

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with such gridable vehicles, that is, plug-in electric vehicles (BEVs and PHEVs), along with grid capacity. Since maximum vehicles are parked an average of 95 percent of the time, these vehicles batteries could be used to let electricity flow from the car to the power lines. V2G technology is basically a version of battery to grid power applied to vehicles. There are three different versions of the V2G technology.

PROPOSED SYSTEM

V2G mode is a kind of bidirectional energy exchange model in which plug-in electric vehicles (EVs) communicate with the power grid to sell demand response services by either delivering electricity into the grid or by throttling their charging rate[1][2]. The large scale application of V2G EV will bring a potential influence on the power grid [3-13]. It will increase the grid load, on the other hand it can also provide ancillary service by transferring electricity to the power grid as a smart energy storage unit. Currently, several studies have been conducted on the modelling of EV load and its impact on the grid. Reference [4] develops mathematical model of Plug-in Hybrid Electric Vehicles (PHEVs) combined with distribution system components model, and the developed model is used to study the impact of uncoordinated and coordinated charging of PHEVs in distribution system. Oak Ridge National Laboratory (ORNL) is developing simulation models and energy management scenarios using the actual solar production and residential energy usage data, and a PHEV [5]. Reference [6] studies the impact of EVs on the grid in different scenarios with different seasons.

Methodology for modelling and analysing of the load demand in a distribution system due to EV battery charging are presented in reference [7][8]. Reference [9] proposes a coordinate charging strategy with the goal to minimize the power losses and maximize the main grid load factor. The penetration of EVs may bring potential challenges to electric utility especially at the distribution level. The conclusion of reference [10] indicates that the load created by PHEVs in some cases may exceed the distribution transformer capacity. Reference [11] proposes a comprehensive approach for evaluating the impact of different levels of PHEV penetration on distribution network investment and incremental energy losses. V2G mode EVs can exchange energy with the power grid. However, the previous references only focus on characteristics study of the charging load without considering the discharging process. While in reference [12] [13], the authors investigate different charging strategies for EVs with respect to their impact on the local power distribution network of a residential area. They assess the optimal car battery dis/charging scheduling to achieve peak shaving, reduction of the variability (over time) of the load, and cost reductions for electric mobility, respectively. The aim of this paper is to model different kinds of EV loads by considering most of the impact factors on regional EV load. Then this paper will simulate the impact of different EV models and different EV scales on the grid based on the grid load curve of a real district in China.

The result of applying these rules is an update list in which non direct-feed through blocks appear at the head of the list in no particular order followed by direct-feed through blocks in the order required to supply valid inputs to the blocks they drive. During the sorting process, Simulink checks for and flags the occurrence of algebraic loops, that is, signal loops in which an output of a direct-feed through block is connected directly or indirectly to one of the block's inputs. Such loops seemingly create a deadlock condition since Simulink needs the input of a direct-feed through block in order to compute its output. However, an algebraic loop can represent a set of simultaneous algebraic equations (hence the name) where the block's input and output are the unknowns. Further, these equations can have valid solutions at each time step. Accordingly, Simulink assumes that loops involving direct-feed through blocks do,

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in fact, represent a solvable set of algebraic equations and attempts to solve them each time the block is updated during a simulation.

TABLE I. CURRENT SET-POINTS TO EV BATTERIES

Time range (s)	0 to 1	1 to 4	4 to 6
Current set-point to EV_1 battery (A)	0	+80	0
Current set-point to EV_2 battery(A)	0	0	-40

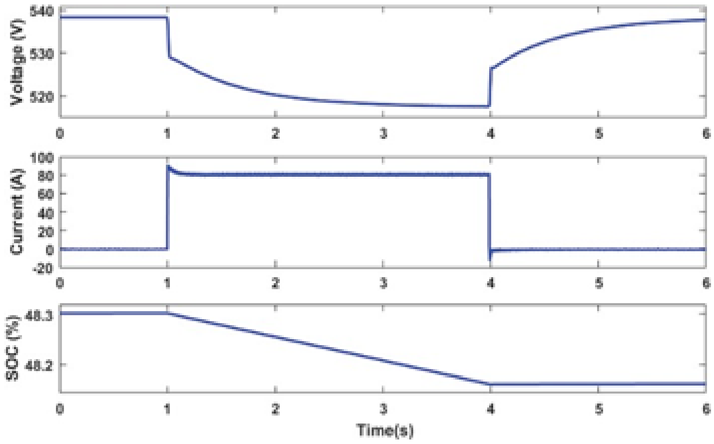

Fig.1.Voltage, current and SOC or EV1battery during V2G operation

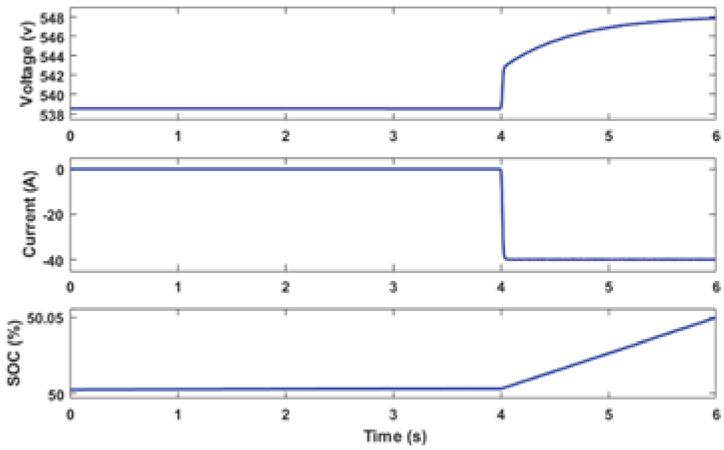

Fig.2.Voltage, current and SOC or EV2 battery during G2V operation

The active power contribution from various components of the system is shown. The grid power changes to accommodate the power transferred by the EVs. The negative polarity of the grid power from 1s to 4s shows that the power is being fed to the grid from the vehicle. The change in polarity of grid power at 4s shows that the power is supplied by the grid for charging the vehicle battery. This demonstrates the V2G-G2V operation. Also, the net power at PCC is zero showing an optimal power balance in the system.

The dc bus voltage is regulated at 1500 V by the outer voltage control loop of the inverter controller and is shown in Fig. 9. This in turn is achieved by the inner current control loop tracking the changed d-axis reference current as shown in Fig. 10.

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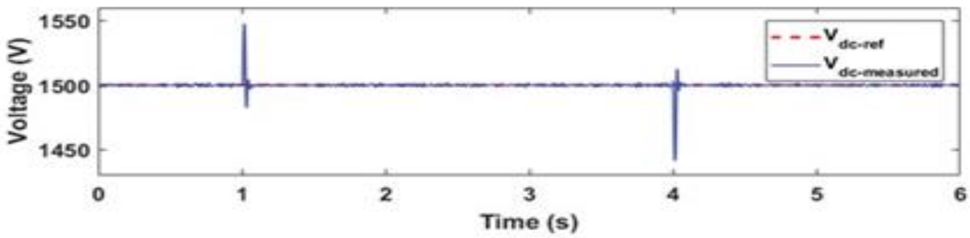

Fig.3.Variation in dc bus voltage

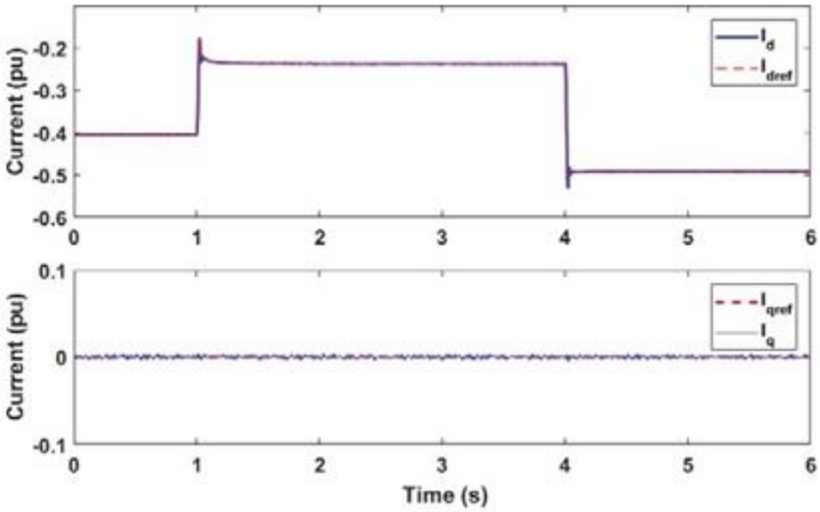

Fig.4.Reference current tracking by inverter controller

The grid voltage and current at PCC are shown in Fig. 11. Voltage and current are in phase during G2V operation and out of phase during V2G operation showing the reverse power flow.

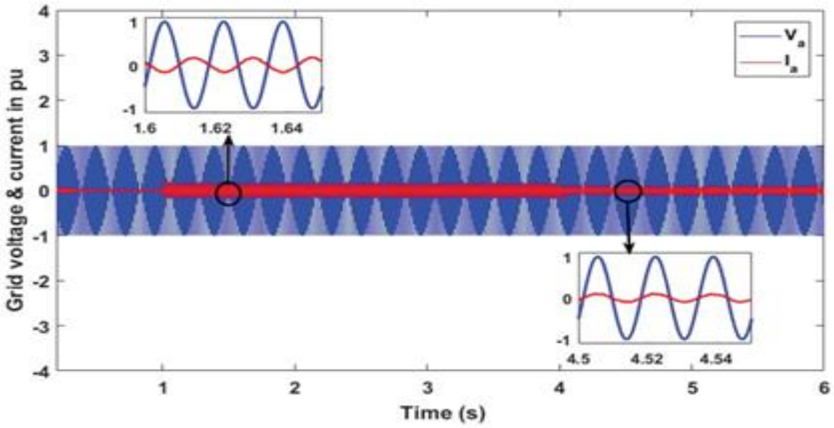

Fig.5.Grid voltage and grid injected current during V2G-G2V operation

Total harmonic distortion (THD) analysis is done on the grid injected current and the result is shown in Fig. 12. According to IEEE Std. 1547, harmonic current distortion on power systems 69 kV and below are limited to 5% THD. The THD of grid- injected current is obtained as 2.31 % and is achieved by the judicious design of LCL filter.

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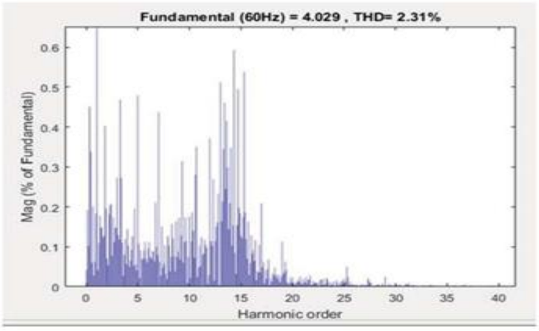

Fig. 6. Harmonic spectrum and THD of grid-injected current

CONCLUSION

Modelling and design of a V2G system in a micro-grid using dc fast charging architecture is presented in this paper. A dc fast charging station with off-board chargers and a grid connected inverter is designed to interface EVs to the micro- grid. The control system designed for this power electronic interface allows bi-directional power transfer between EVs and the grid. The simulation results show a smooth power transfer between the EVs and the grid, and the quality of grid injected current from the EVs adheres to the relevant standards. The designed controller gives good dynamic performance in terms of dc bus voltage stability and in tracking the changed active power reference. Active power regulation aspects of the micro- grid are considered in this work, and the proposed V2G system can be utilized for several other services like reactive power control and frequency.

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