IJARSCT

ISSN (Online) 2581-9429

International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)

Impact Factor: 6.252

Volume 2, Issue 5, June 2022

Vehicle to Grid (V2G) & Grid to Vehicle (G2V) Technology using Dc Fast Charging Architecture

Shaila P. Boga[1] and Vishal M. Pimpalkar[2]
PG Scholar, Department of Electrical Engineering[1]
Assistant Professor, Department of Electrical Engineering[2]
Ballarpur Institute of Technology, Ballarpur, India

Abstract: *In micro-grids, electric vehicle batteries can be used as potential energy storage devices. They can assist in micro-grid energy management by storing energy when there is a surplus (Grid-To-Vehicle, G2V) and supplying energy back to the grid when there is a demand for it (Vehicle-To-Grid, V2G). In order to realise this concept, proper infrastructure and control systems must be established. This study presents an architecture for establishing a V2G-G2V system in a micro grid employing level-3 fast charging of electric vehicles. A micro-grid test system with a dc fast charging station for connecting EVs is modelled. V2G-G2V power transfer is demonstrated through simulation research. The findings of the tests reveal that EV batteries may actively regulate power in the microgrid using G2V-V2G modes of operation. The charging station's design guarantees that grid injected current has little harmonic distortion, and the controller provides good dynamic performance in terms of dc bus voltage stability.*

Keywords: Electric Vehicle, Vehicle to Grid, Grid to Vehicle, Grid connected inverter

I. INTRODUCTION

Energy storage systems are crucial components of a microgrid because they allow intermittent renewable energy sources to be integrated. When EV batteries are plugged in for charging, they can be used as storage devices in micro-grids. The majority of personal transportation cars are parked for around 18 hours each day, during which time they are an idle asset. EVs have the ability to assist in micro-grid energy management by storing excess energy (G2V) and feeding it back to the grid when there is a demand for it. V2G in the general power grid confronts several obstacles, including being difficult to control, requiring a large number of EVs, and being difficult to implement quickly [1]. In this scenario, a V2G system in a micro-grid is simple to create. For electric vehicles, the Society of Automotive Engineers defines three charging levels.

A plug connects to the vehicle's on-board charger and a conventional household (120 V) outlet for Level 1 charging. This is the slowest charging method and is suitable for those who travel less than 60 km per day and have all night to charge. Level 2 charging employs a specialised Electric Vehicle Supply Equipment (EVSE) to provide power at 220 V or 240 V and up to 30 A at home or at a public station. DC rapid charging is another name for level 3 charging. DC fast charging stations deliver up to 90 kW of charging power at 200/450 V, cutting charging time in half to 20-30 minutes. Due to the rapid power transfer necessary when EVs are used for energy storage, DC fast charging is chosen for implementing a V2G architecture in a microgrid. The dc bus can also be utilised to include renewable generation into the system.

The V2G idea has been used in the general power grid for services such as peak shaving, valley filling, regulation, and spinning reserves in the majority of prior studies [2]. The development of V2G technology in a micro-grid facility to support power generation from intermittent renewable energy sources is still in its early stages. In addition, most of the works described [3] use level 1 and level 2 ac charging for V2G technology. These ac charging systems are limited by the onboard charger's power rating. Another problem is that the distribution infrastructure was not built to handle bi-directional energy flow. In this case, research is needed to design technically viable charging station architectures to enable V2G technology in micro-grids. In a micro-grid facility, this work presents a dc rapid charging station infrastructure with V2G functionality. A solar photovoltaic (PV) array is integrated into the micro-grid using the same dc bus that connects EVs. Off-board chargers can provide high-power bi-directional charging for EVs under the proposed architecture. The suggested model's effectiveness is assessed using MATLAB/Simulink simulations in both V2G and G2V modes of operation. The organization of the paper is section 2 consist V2G configuration for DC fast charging station. Section 3 consist control system of DC fast charging station. Section 4 will elaborate Microgrid test system configuration. Simulation and results explained in detail in section 5. Section 6 conclude the paper.

1.1 V2G Configuration for DC Fast Charging

Off-board chargers connect electric vehicle batteries to the dc bus. Through an LCL filter and a step-up transformer, a grid linked inverter connects the dc bus to the utility grid. The charging station's most critical components are listed below.

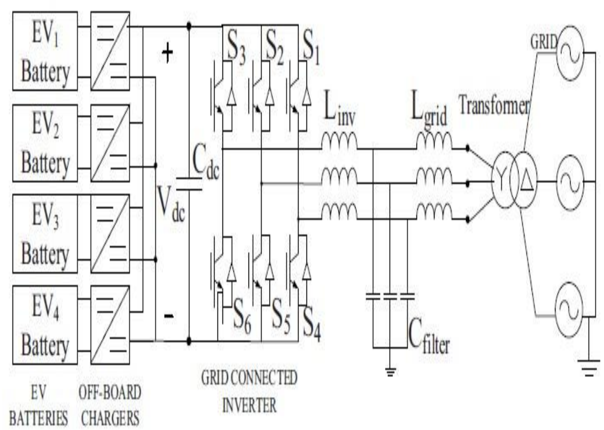

Fig.1 EV charging station for fast DC charging

1.2 Battery Charger Configuration

The chargers for dc fast charging are placed off-board and housed in an EVSE. The essential building component of an off-board charger with V2G functionality is a bidirectional dc-dc converter. It connects the electric vehicle battery system to the dc distribution grid. Figure 2 depicts the converter arrangement. It comprises of two IGBT/MOSFET switches controlled by complementary control signals at all times.

A. Charging Mode (Buck activate)

The converter functions as a buck converter when the upper switch is on, scaling down the input voltage to battery charging voltage. Current travels through the switch and inductor to the battery when the switch is turned on. This is the charging process, in which power is transferred from the grid to the car (G2V). When the switch is turned off, the current flows back through the lower switch's inductor and diode, completing the circuit. The battery voltage is given by:

$$V_{Batt} = V_{DC} * D \qquad (1)$$

B. Discharging Mode (Boost activate)

The converter operates as a boost converter when the lower switch is on, ramping up the battery voltage to the dc bus voltage. When the switch is in the on position, current flows via the inductor and is completed by the anti-parallel diode of the top switch and the capacitor. In this situation, the net power flow is from the vehicle to the grid (V2G), while the battery is in discharge mode. The output voltage during boost mode of operation is given by: If the capacitor is large enough to generate a constant dc voltage, the output voltage is given by:

$$V_{DC} = \frac{V_{Batt}}{1-D'} \qquad (2)$$

Where D' is the duty cycle of the lower switch.

LCL Filter and Grid Connected Inverter

The grid connected inverter (GCI) converts dc bus voltage to three-phase ac voltage and permits current to flow backwards through anti-parallel diodes in each leg's switches (Fig. 1). An LCL filter is connected to the inverter's output terminals to reduce harmonics and produce pure sinusoidal voltage and current. This work's design technique for calculating the LCL filter parameters is based on [4].

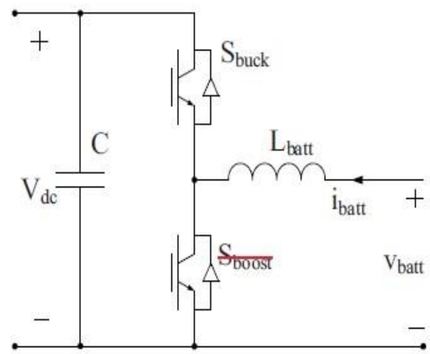

Fig.2 Battery charger configuration

II. CONTROL SYSTEM

2.1 OFF Board Charger Control

For charge/discharge control of the battery charger circuit, a constant current control approach [5] using PI controllers is used, as shown in Fig.3. To determine the polarity of the current signal and choose between charging and discharging modes of operation, the controller compares the reference battery current to zero. After selecting the mode, the reference current is compared to the measured current, and the error is routed via a PI controller to generate the *Sbuck/Sboost* switching pulses. During the charging process, *Sboost* will be turned off, and *Sbuck* will be turned off during the discharging phase

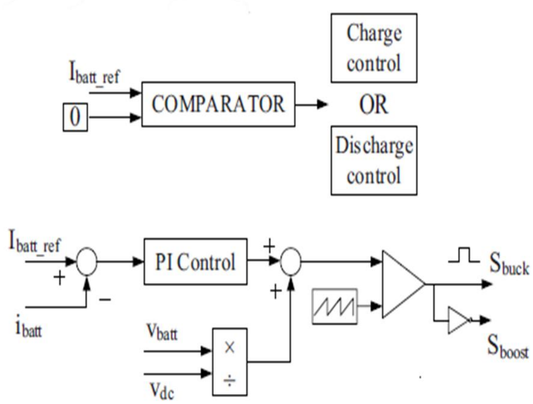

Fig.3 Constant current control strategy

IV. INVERTER CONTROL

For the inverter controller, a cascade control in synchronous reference frame is presented. Figure 4 [4] shows the usual vector control utilising four PI controllers in a layered loop. Two outside voltage control loops and two inner current control loops make up the control structure. The active ac current is controlled by the d-axis inner loop, while the dc bus voltage is controlled by the outer loop. Similarly, the q-axis outer loop adjusts the reactive current, which is regulated by the q-axis inner current loop, to regulate the ac voltage magnitude. To boost performance during transients, *dq* decoupling terms L and feedforward voltage signals have been introduced.

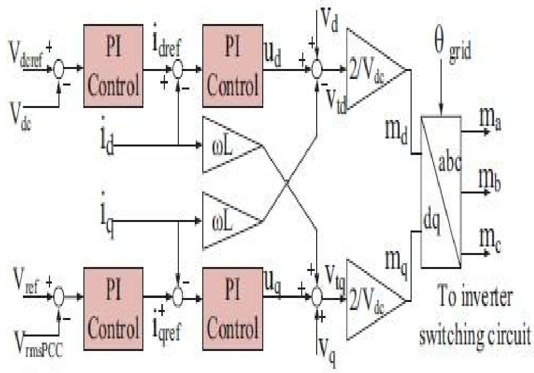

Fig.4 Inverter control system

V. MICROGRID TEST SYSTEM

Figure 5 shows the configuration of the micro-grid test system with the dc rapid charging station. The system's generation sources include a 100 kW wind turbine (WT) and a 50 kW solar PV array. The EV battery storage system comprises of four EV batteries that are connected to the charging station's 1.5 kV dc bus through off-board chargers. A boost converter with a maximum power point tracking (MPPT) controller connects the solar PV to this dc bus as well. A 25 kV distribution feeder and a 120 kV equivalent transmission system make up the utility grid. At the point of common coupling, the wind turbine-driven doubly-fed induction generator is connected to the micro-grid (PCC). Transformers are used to increase voltages and connect the ac systems to the utility grid. Figure 5 shows a proposed setup for a microgrid test system**.**

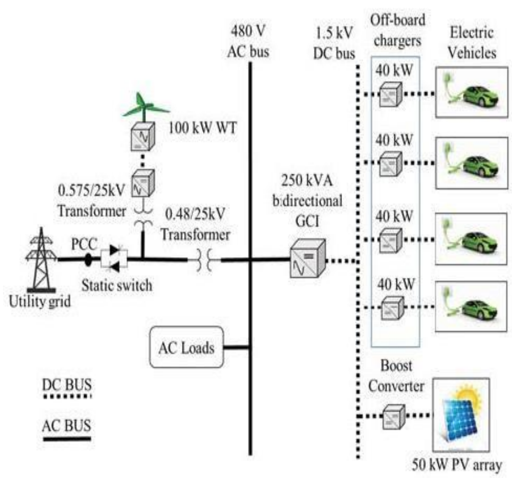

Fig. 5 Proposed microgrid test system configuration

VI. SIMULATION AND RESULTS

The process for designing charging stations was adopted from [4], and the obtained parameter values are listed in Appendix. The wind turbine is set to its rated speed, producing a maximum output power of 100 kW. The solar PV system is tested under normal test circumstances (1000W/m2 irradiance and 25°C temperature) and produces a maximum power output of 50 kW. The 480 V ac bus is coupled to a 150 kW resistive load. For unity pf operation, the reactive current reference to GCI is set to zero. The initial state of charge (SOC) of the electric vehicle batteries is set to 50%. Once the steady state conditions have been achieved, the V2G-G2V power transfer is performed using the batteries of

EV1 and EV2 (Fig. 1). Table I shows the current set-points for the battery charging circuits of the EV1 and EV2 batteries, with the results illustrated in the following images. Figures 6 and 7 show the battery parameters for EV1 in V2G and EV2 in G2V mode

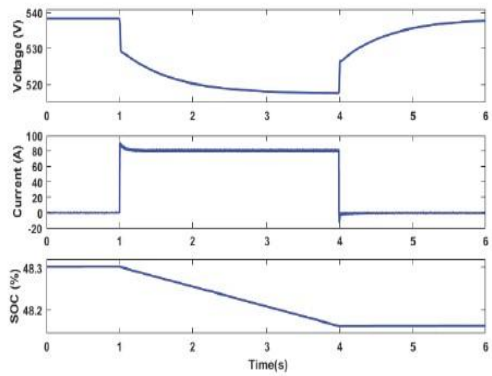

Fig. 6 Voltage, current, and SOC of EV_1 battery during V2G operation

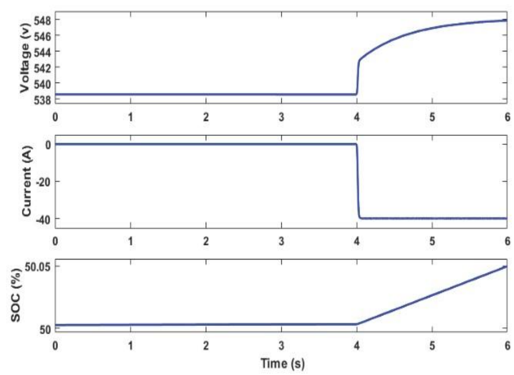

Fig 7 voltage, current, and SOC of EV2 battery during G2V operation

Figure 8 depicts the active power contribution from various system components. To accommodate the electricity transferred by the EVs, the grid power adjusts. The negative polarity of the grid power from 1s to 4s indicates that the car is supplying power to the grid. At 4s, the polarity of grid power changes, indicating that the grid is supplying electricity to charge the vehicle battery. The V2G-G2V operation is demonstrated in this example. Furthermore, the net power at PCC is zero, indicating that the system's power balance is ideal.

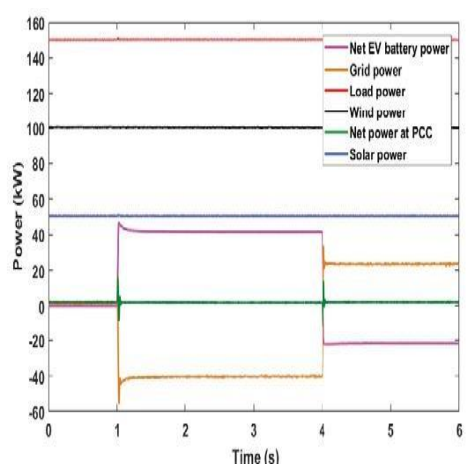

Fig. 8 Active power profile of various components in the system

The inverter controller's outer voltage control loop regulates the dc bus voltage at 1500 V, as shown in Fig. 9. The inner current control loop, as shown in Fig. 10, does this by tracking the altered d-axis reference current. Figure 11 depicts the grid voltage and current at PCC.

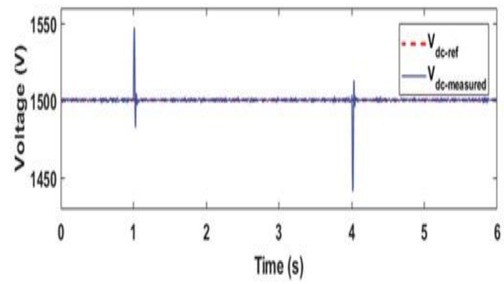

Fig.9 Variation in DC bus voltage

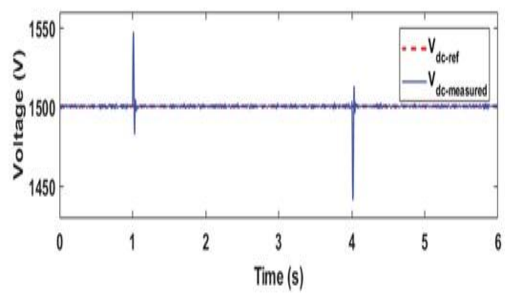

Fig.10 Reference current tracking by Inverter controller

The reverse power flow is shown by voltage and current being in phase during G2V operation and out of phase during V2G operation

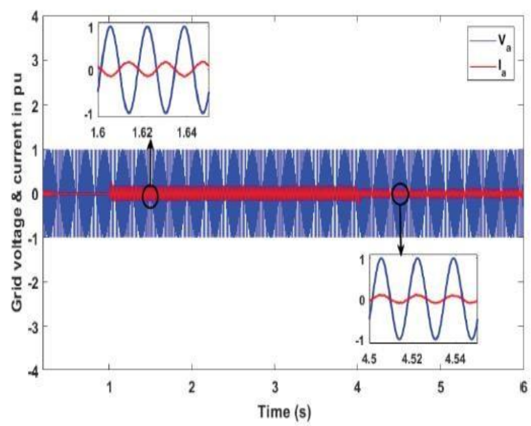

Fig.11 Grid voltage and grid injected current during V2G-G2V operation

The grid injected current is subjected to a total harmonic distortion (THD) analysis, as shown in Fig. 12. Harmonic current distortion for power systems 69 kV and below is limited to 5% THD, according to IEEE Std. 1547. The grid injected current has a THD of 2.31 percent, which is achieved because to the careful design of the LCL filter.

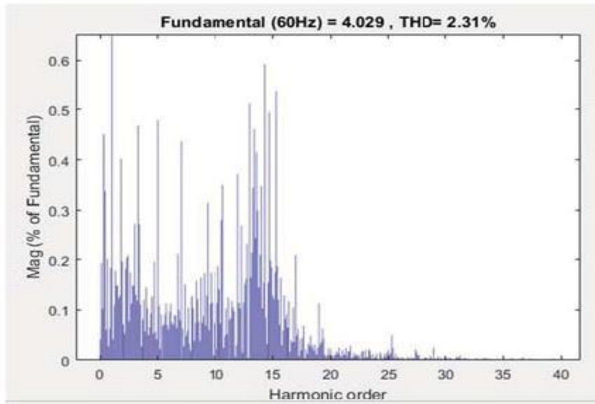

Fig. 12 Harmonic spectrum and THD of grid-injected current

VII. CONCLUSION

This study presents the modelling and design of a V2G system on a micro-grid using a dc rapid charging architecture. To link EVs to the microgrid, a dc rapid charging station with off-board chargers and a grid-connected inverter is created. This power electro The simulation findings show a seamless power transfer between the EVs and the grid, with grid injected current from the EVs meeting all applicable standards. In terms of dc bus voltage stability and tracking the altered active power reference, the developed controller performs well dynamically. This paper considers the microgrid's active power regulation features, and the proposed V2G system can be used for a variety of different services such as reactive power control and frequency regulation. Future research should focus on the design of a supervisory controller that sends command signals to the individual EV charging controllers.

REFERENCES

[1]. C. Shumei, L. Xiaofei, T. Dewen, Z. Qianfan, and S. Liwei, “The construction and simulation of V2G system in micro-grid,” in Proceedings of the International Conference on Electrical Machines and Systems, ICEMS 2011, 2011, pp. 1–4.

[2]. S. Han, S. Han, and K. Sezaki, “Development of an optimal vehicle-togrid aggregator for frequency regulation,” IEEE Trans. Smart Grid, vol. 1, no. 1, pp. 65–72, 2010.

[3]. M. C. Kisacikoglu, M. Kesler, and L. M. Tolbert, “Single-phase on-board bidirectional PEV charger for V2G reactive power operation,” IEEE Trans. Smart Grid, vol. 6, no. 2, pp. 767–775, 2015.

[4]. A. Arancibia and K. Strunz, “Modeling of an electric vehicle charging station for fast DC charging,” in Proceedings of the IEEE International Electric Vehicle Conference (IEVC), 2012, pp. 1–6.

[5]. K. M. Tan, V. K. Ramachandaramurthy, and J. Y. Yong, “Bidirectional battery charger for electric vehicle,” in 2014 IEEE Innovative Smart Grid Technologies - Asia, ISGT ASIA 2014, 2014, pp 4. 406–411.

Appendix

Parameter	**Value**	**Parameter**	**Value**
Rated Capacity	250 kVA	EV rated power	40 kW
VBatt	500 V	Battery Capacity	48 Ah
Cdc	850 µF	C*filter*	133 µF
Linv	0.25 mH	L*grid*	0.25 mH

Charging Station Parameter