Integrating Electric Vehicle into Micro Grid for Quality Power Exchange

Anubhav[1] Dr. Tarlochan Kaur[2]
[1,2]Department of Electrical Engineering
[1,2]PEC University of Technology, Chandigarh, India

Abstract— Integrating a large number of Electric Vehicles (EV) into a distribution grid demands to develop a system to overcome the power quality issues. A smart compatible integration of the electric vehicle with the distribution grid is developed in this paper to ensure quality power exchange between the EV and grid. An EV is connected with a micro grid comprising a solar panel and wind turbine through a bi-directional converter. Two aspects of integrating EVs into the grid i.e., grid to vehicle and vehicle to grid are proposed to ensure quality power exchange. Simulations are done in MATlab. Results show the feasibility of integrating EVs into a distribution system.

Key words: Electric Vehicles (EV), Micro grid, Quality Power Exchange

I. INTRODUCTION

Integrating a large number of EVs into an existing distribution power system poses serious threats to the grid such as overloading, voltage imbalance and harmonics. Therefore, it is imperative to take great care while integrating EVs into the grid. Components of the EV charger are to be carefully designed to ensure a quality interaction. Also, to ensure fast DC charging, work has been done for a level 3 charger [1].

The bi-directional DC-DC converter used to connect EV with grid employs constant voltage and constant current strategy. Finally, total harmonic distortion present in the output current is calculated with and without EV which prove the feasibility of integration of EV into the grid.

II. COMPLETE SIMULINK MODEL OF MICROGRID

The model proposes a 100kW DC micro grid 500V DC link voltage which consists of a 50 kW photovoltaic panel, 50 kW wind turbine, batteries, converters and a local load of 80kW. The complete Simulink model of micrgrid along with battery controller and DC-DC converter is shown in Fig. 1.

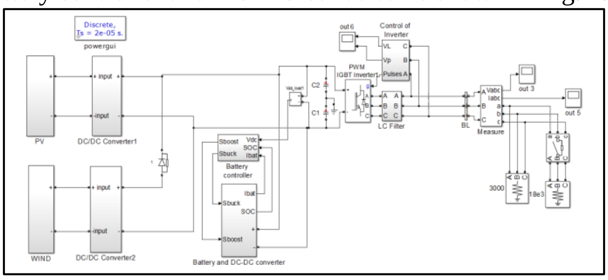

Fig. 1: Complete Simulink model of microgrid

III. EV CHARGER UNIT

For charging and discharging the battery of EV a buck-boost converter is implemented to ensure quality power exchange. It is an off board converter to which the battery is directly connected as shown in Fig. 2. This model verifies the bi-directional operation of Vehicle to Micro grid system where the micro grid is connected to a typical EV lithium-ion battery of nominal voltage 330V and 48.5Ah capacity.

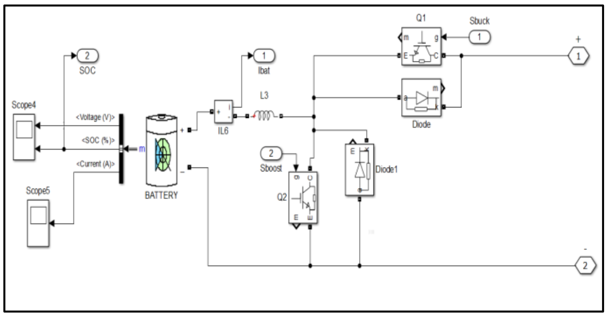

Fig. 2: Simulink model of EV battery charger unit

IV. EV BATTERY CONVERTER CONTROL

For the battery charger, two control techniques, including constant voltage (CV) and constant current (CC), are applied for battery charging and discharging modes respectively. In the constant voltage strategy, the battery operates as a voltage source, and the converter operates in buck mode for battery charging. In the constant current strategy, the EV battery operates as a current source, which is employed for controlling the charger while operating in V2G mode. In this mode, the converter operates in boost mode. Both constant-current and constant-voltage control schemes are integrated and incorporated together to accomplish battery charging and discharging requirements as shown in Fig. 3. The controller consists of two control loops—the first is an inner fast current loop (PI 2) as shown in Fig. 4 and the second is an outer slow voltage loop (PI 1) as shown in Fig. 5.

Pulse generators are used for generating the pulses and operating the two switches (IGBT). Data Type Conversion block is used to have the Real World Values of the input and the output to be equal. Output data type is selected to Boolean because it converts real, nonzero numeric values including NaN (not a number) and Inf (infinite) to boolean true (1).

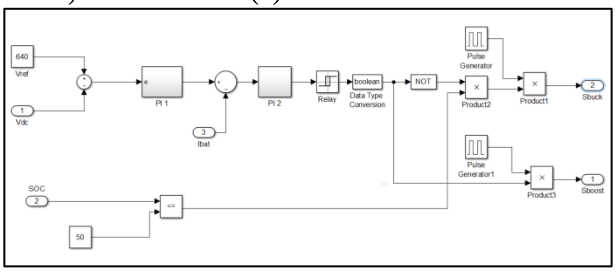

Fig. 3: CC and CV control mechanisms

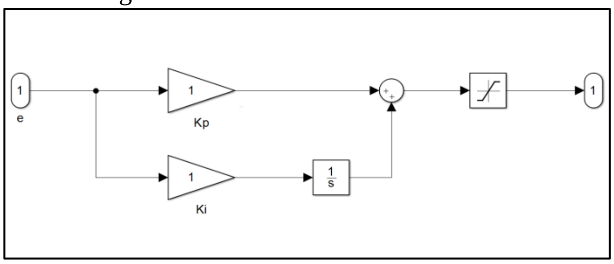

Fig. 4: PI 2 Controller

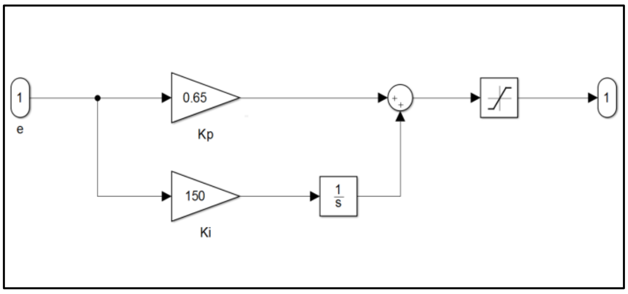

Fig. 5: PI 1 Controller

A. EV Charging Mode (M2V operation)

Constant voltage strategy is employed in this mode. The bi-directional converter operates in buck mode during charging of the battery. Switching device (IGBT) Q1 becomes active while Q2 remains inactive. The difference between reference voltage and battery voltage is fed to PI 1 controller, and the output is considered as the current reference, which is used as reference to the constant current controller, PI 2. If the state of charge (SOC) is below 50% the battery will charge in constant voltage mode. The results obtained after running the simulation are shown in Fig. 6, Fig. 7 and Fig. 8. During the charging, the state of charge of the battery increases and the voltage across the battery remains constant due to PI 1 controller. As the current is flowing into the battery, power of the battery is positive.

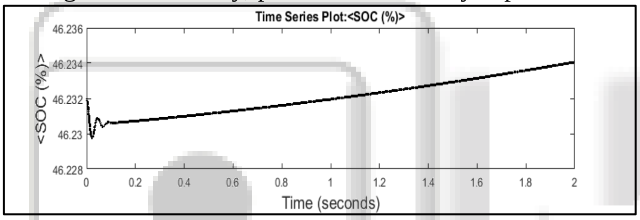

Fig. 6: SOC of battery

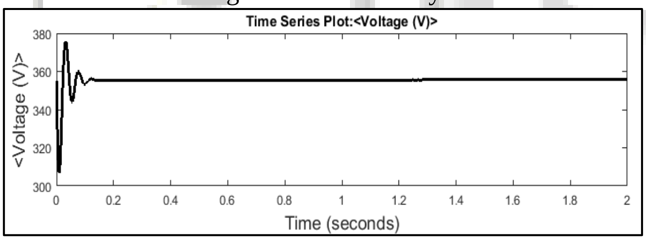

Fig. 7. Voltage of battery during charging

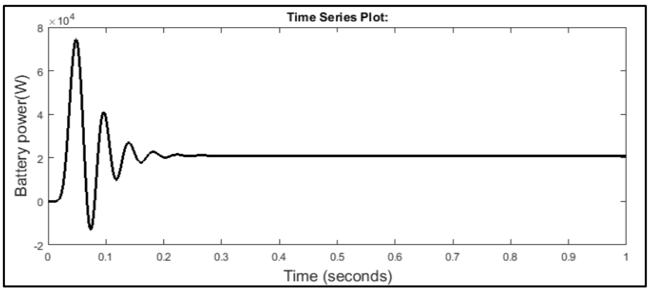

Fig. 8: Battery power during charging

B. EV Discharging Mode (V2M operation)

In the discharging mode, the high-side switch (Q1) of the converter is blocked, and by running the lower switch (Q2) antiparallel to the diode, it works as a Boost converter. During discharging mode, the voltage of the battery is boosted to a higher value and keeps DC bus voltage constant for inverter functioning to supply the load. Control approach is based on cascading outer PI controller with inner PI controller. The PI 2 output is considered as the duty cycle to run the corresponding switch.

The decreasing SOC of the battery is shown in Fig. 9. The battery current is negative as it flows out of the battery as shown in Fig. 10. Due to negative current, power of the battery is also negative as shown in Fig. 11.

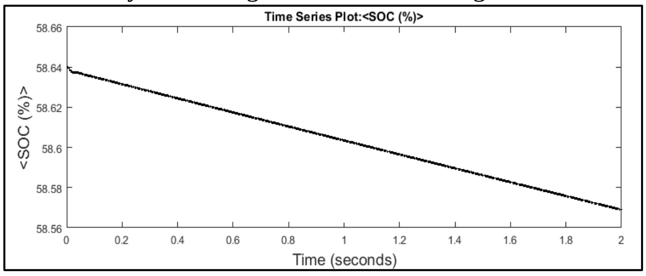

Fig. 9: SOC of battery during discharging

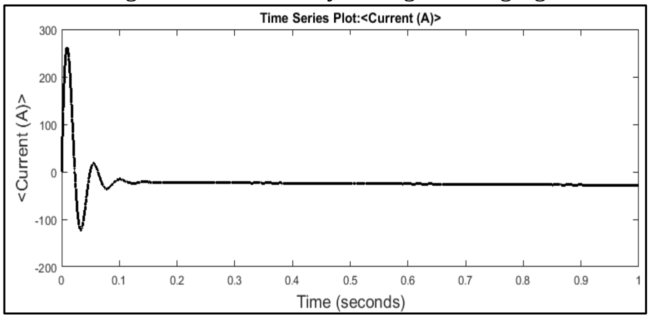

Fig. 10: Battery current during discharging

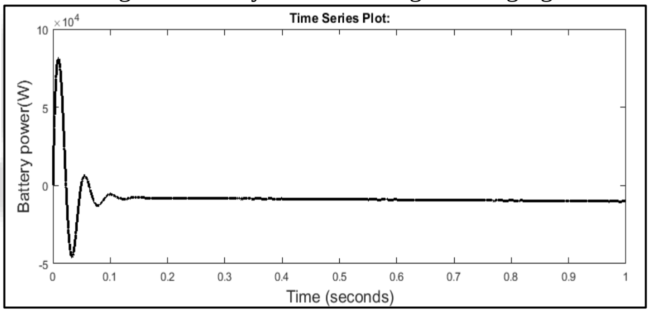

Fig. 11: Battery power during discharging

V. FFT ANALYSIS OF THE OUTPUT CURRENT

A. Vehicle to Microgrid

Output current of the micro grid in V2M mode is shown in Fig. 12. FFT analysis of the output current is shown in Fig. 13. The current THD is found to be 8.41%.

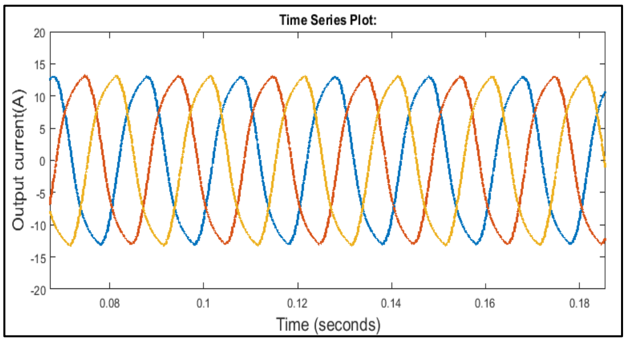

Fig. 12: Output current in V2M mode

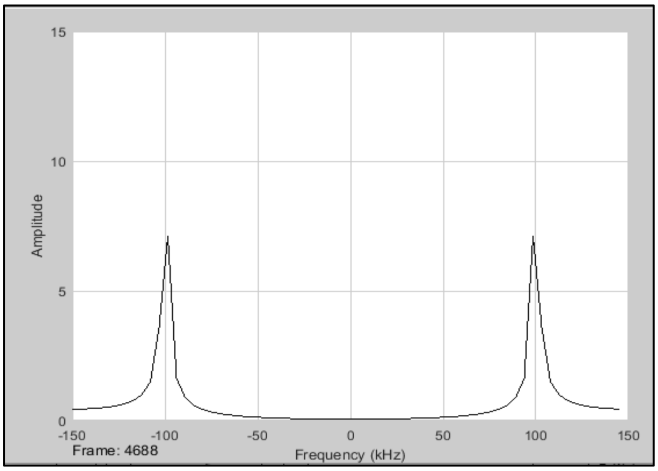

Fig. 13: FFT analysis of output current in V2M mode

B. Microgrid without Vehicle

Waveform of the output current in the absence of the vehicle is shown in Fig. 14. FFT analysis of the output current is shown in Fig. 15. After the analysis the THD is found to be 16.24%. This proves that employing the battery of the electric vehicle can sufficiently reduce the harmonics.

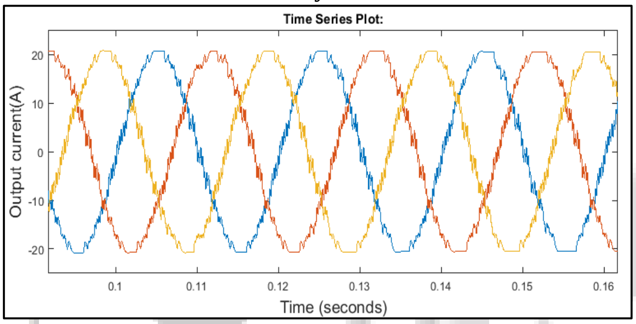

Fig. 14: Output current without EV

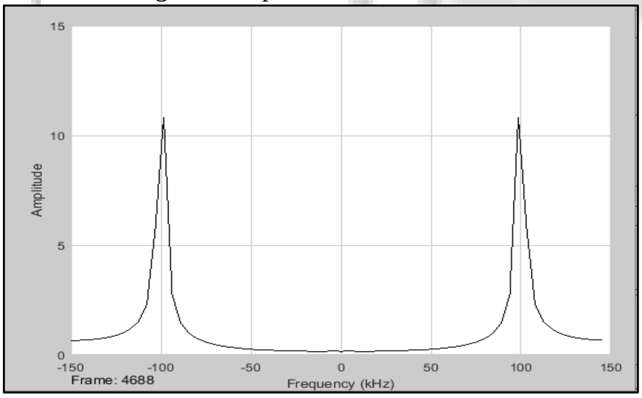

Fig. 15: FFT analysis of output current without EV

VI. CONCLUSION

A smart converter for integrating EV into the distribution grid has been proposed. Models are implemented in MATlab Simulink. The feasibility of charging and discharging of EV is illustrated with the help of simulation results. Integrating the EV into the grid has bring down the harmonics sufficiently.

REFERENCES

[1] A. Arancibia, K. Strunz, "Modeling of electric vehicle charging station for fast DC charging" Electric Vehicle Conference (IEVC), 2012 IEEE International. Karlsson P. Svensson J., "DC bus voltage control for distributed power systems", Power Electronics, IEEE Transaction on Vol.18, no.6, pp. 1405-1412, nov 2003.