EE665: Power Electronics Systems for Electrical Vehicles.
Course Project Report on
Simulation of Three Phase Two Level Controlled Bi-directional ac-dc Converter with Bi-directional Full Bridge Isolated Converter System

by Group-20
Abhijeet Anand (214102101)
Dnyaneshwar H. Patale(214102103)
Gadipe Sachin Kumar(214102104)
Sanjay Kumar Sahu(214102115)
Sanjay Shooray(214363010)
Instructor: Dr. CHANDAN KUMAR

1 Objective

To simulate a Three Phase two level controlled Bidirectional ac-dc converter with Bidirectional full bridge isolated Converter as a battery charger. The details of converter system and other ratings are given in the table below. The charging system has to be designed such that it charges from 75% of State of Charge (SOC) to 85% (SOC). The charging system will charge the battery with:

- 75% to 80% charging in constant current mode.
- 80% to 85% charging in constant voltage mode.

s.no	Specification	value	units
1	Input Voltage	6.6 (L-L)	KV
2	Frequency	50	Hz
3	Battery Voltage	400	V
4	Battery Energy rating	70	KWhr
5	Battery charging time (20-80 SOC)	1.5	hr
5	Input Power factor	1	–
6	Input Current THD	5%	–
7	Output Voltage ripple fo ac-dc converter	5%	–

2 General Block diagram

Smart grid and electric vehicles (EVs) are widely used all over the world. As the key role, the Vehicle-to-Grid (V2G) has been attracting increasing attention.e bidirectional grid-connected AC/DC converter is one of the indispensable parts in the V2G system, which can realize bidirectional power flow and meet the power quality requirements for grid. A three-phase bidirectional grid-connected AC/DC converter is presented in this paper for V2G systems.It can be used to achieve the bidirectional powerflow between EVs and grid, supply reactive power compensation, and smooth the power grid fluctuation. Firstly, the configuration of V2G systems is introduced, and the mathematical model of the AC/DC converter is built. en, for bidirectional AC/DC converters, and the analysis of PI control strategy is proposed and the controller is designed and simulation model is established based on MATLAB/Simulink.

The configuration of Battery charging system is shown in Figure 1; the system consists of three parts, AC grid, converters, and loads. AC grid supplies original AC voltage to converters through a transformer, of which the ratio is 9600:500. Converters consist of AC/DC converter and DC/DC converter. The AC/DC converters transform AC energy to DC energy. The bidirectional DC/DC converter connects the battery to the DC bus.

3 AC-DC Converter

The basic topology of three phase PWM boost rectifier is shown in Fig.2. For the proper operation of the rectifier, the dc voltage Vdc should at any instant be greater than peak value of ac source voltage V_s(peak). Initially during turn on, the capacitor charges to the peak of source

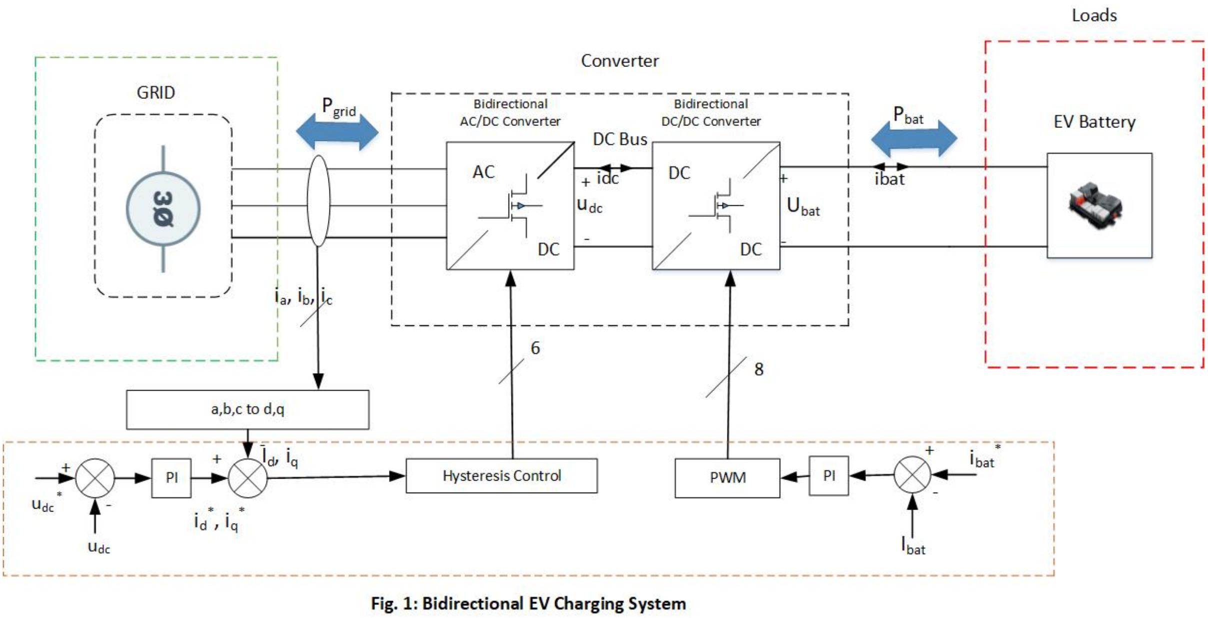

Figure 1: Bidirectional EV charging system

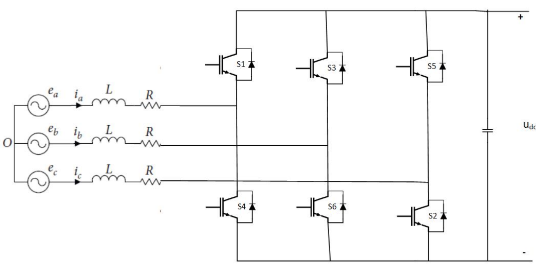

Figure 2: Three phase AC DC converter

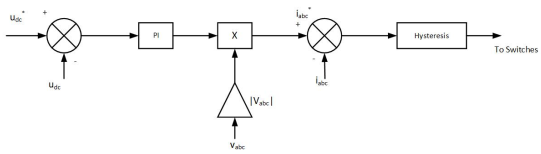

Figure 3: Control circuit for AC-DC converter

voltage through the anti parallel diodes and then the control circuit maintains the reference voltage at the desired value. A voltage controller (Proportional Integral (PI) controller) is used to produce the reference current proportional to the input power needed to maintain the dc link voltage constant. This reference current is multiplied by a sinusoidal unit vector derived from the Unit voltage vectors and thus the reference currents for each phase are generated. These reference currents are compared with the actual one and then fed to the hysteresis band controller.

Rectifier Output voltage:

$$V_{0max} = \frac{3 * V_{ml}}{\pi} = \frac{3 * \sqrt{2} * 6.6}{\pi} = 8.9kV$$

The Transfer function of the PI controller used in the control circuit in the AC-DC converter is as follows:

$$PI_v = 0.1 + \frac{125.6}{s}$$

and Band Width used here is BW = 200 Hz

4 DC-DC Converter

The topology of the bidirectional DC/DC converter is shown in Figure 3, which connects DC bus to battery pack. And the bidirectional H-bridge DC/DC converter will meet the wide voltage requirement of battery. The DC bus voltage of DC/DC converter is denoted as u_{dc}. The filter circuit consists of L and C. Basic controller block diagram for DAB control is shown in figure 5

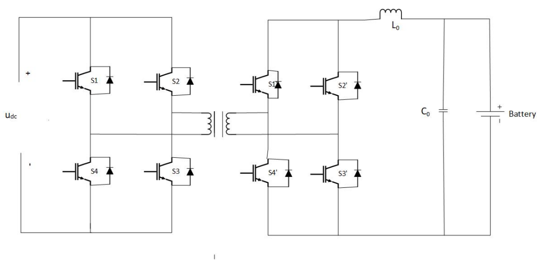

Figure 4: Dual Active Bridge

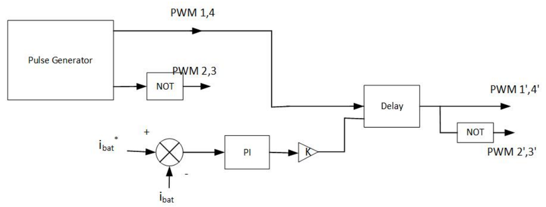

Figure 5: Control circuit fo DC-DC converter

Dual active bridge converter (DAB) is a bidirectional DC-DC converter. It consists of two full bridge converter which is isolated by transformer having high frequency. It can operate as buck and boost converter according to the requirement. The direction of flow of power can be interchange either via source to load or vice-versa by changing the phase shift. It can be used in high power application and has very high efficiency. It contains less number of passive components such as resistance, capacitor and inductor. Therefore, switching losses are very less and this improves the efficiency of the whole system. It has wide application in hybrid electric vehicles, smart grids, micro grids, nano grids, aerospace equipment and so on.

The Transfer functions for constant voltage and constant current are as follows:

$$PI_{cc} = 0.01 + \frac{10}{s}$$

Band width of constant current PI controller is BW = 159 Hz

$$PI_{cv} = 0.005 + \frac{25}{s}$$

Band width of constant voltage PI controller is BW = 795 Hz

5 Calculations

5.1 Battery Current for Constant Current Mode:

$$I = \frac{0.6E_B}{t_cV} = \frac{0.6 * 70 * 10^3}{1.5 * 400} = 70A$$

5.2 Inductor value for DAB:

$$L_0 = \frac{N_1}{N_2}\frac{V_{dc_1}V_{dc_2}}{2f_sP}D(1-D) = 0.103mH$$

5.3 Capacitor calculation for DAB:

$$C_0 = \frac{N_1}{N_2}\frac{V_{dc_1}+\frac{N_1}{N_2}V_{dc_2}}{2f_sL}\frac{T_s}{2\Delta V} = 200\mu F$$

5.4 Capacitance calculation for DC link capacitor:

$$C_{dc} = \frac{2\Delta P_{max}\Delta t}{V_{dc}^2-(V_{dc}-\Delta V_{dcL})^2} = 4700\mu F$$

5.5 Source side filter inductor calculation:

$$L = \frac{V_{dc}}{4hf_{smax}} = 1mH$$

6 Results

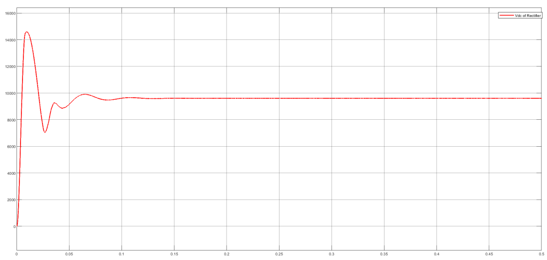

Figure 6: Vdc of Rectifier

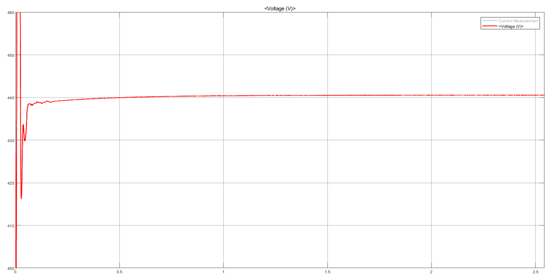

Figure 7: DAB Output at Constant Current

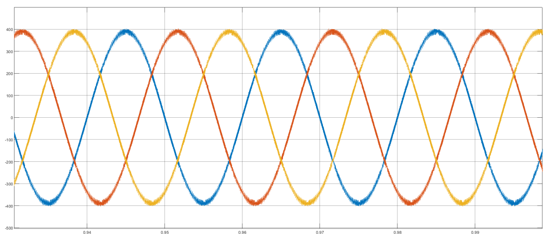

Figure 8: Grid Currents

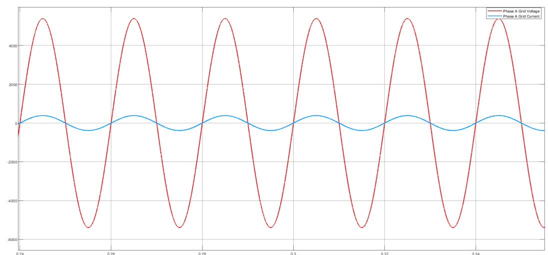

Figure 9: Power factor of the converter

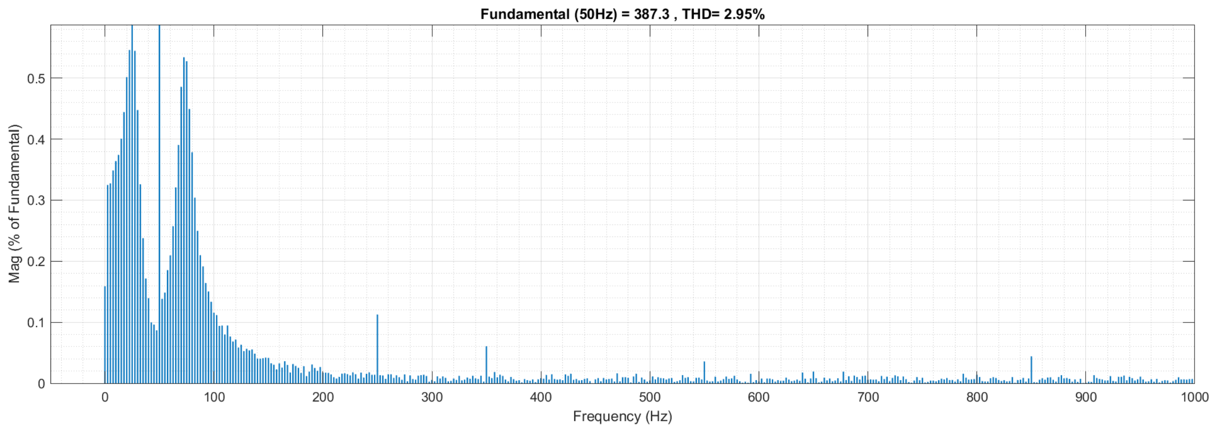

Figure 10: FFT for Grid Current

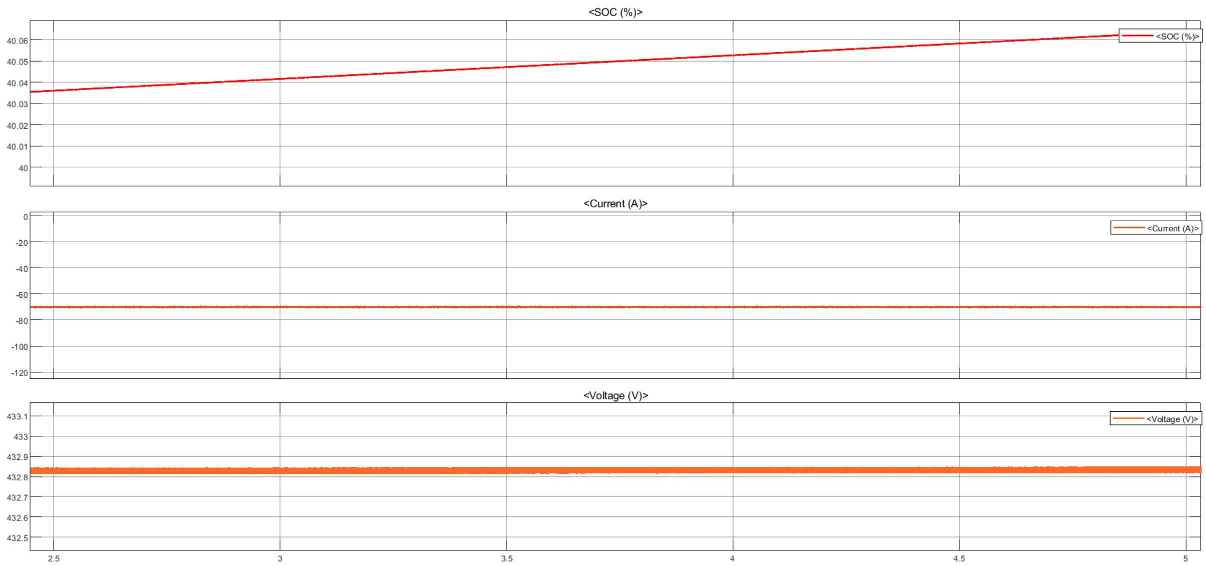

Figure 11: Battery Parameters at CC for SOC of 40%

7 Conclusion

Simulation results show that the converter works well for V2G application with unity power factor, low voltage ripple, high efficiency, and low current THD.

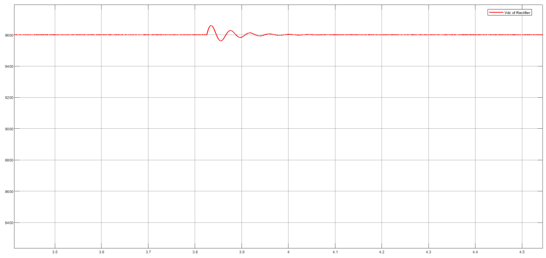

Figure 12: Vdc of rectifier at CCCV

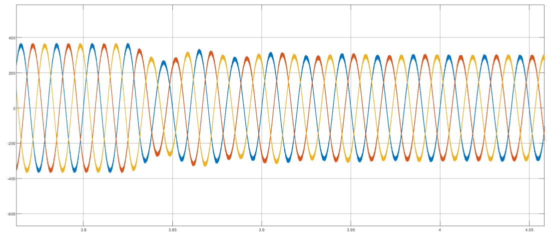

Figure 13: Grid Currents at CCCV

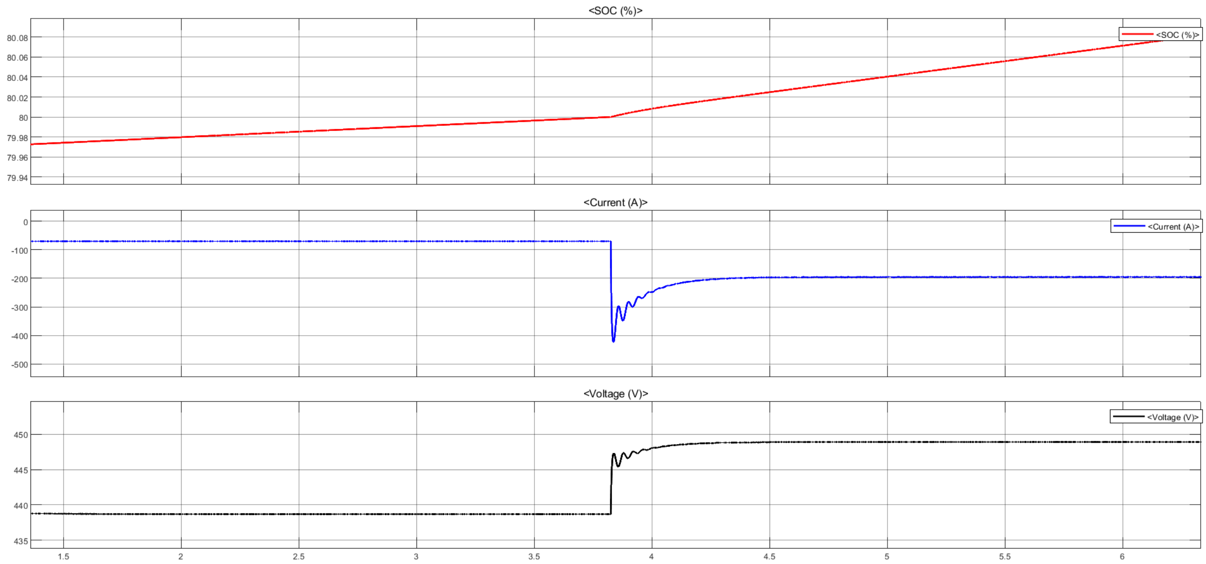

Figure 14: SOC, Current and Voltage of Battery

8 References

[1] Jingang Han, Xiong Zhou, Song Lu, Pinxuan Zhao, "A Three-Phase Bidirectional Grid-Connected AC/DC Converter for V2G Applications", Journal of Control Science and Engineering, vol. 2020, Article ID 8844073, 12 pages, 2020. https://doi.org/10.1155/2020/8844073

[2] Z. Tao and L. Li, “Control loop design and bidirectional control strategy of a bidirectional DC/DC converter,” in Proceedings of the 2017-43rd Annual Conference of the IEEE Industrial Electronics Society (IECON), pp. 5720–5725, Beijing, China, 2017.

[3] B. Singh, G. Shankar and A. Singh, "Modelling of Inverter Interfaced Dual Active Bridge Converter," 2018 International Conference on Computing, Power and Communication Technologies (GUCON), 2018, pp. 680-685, doi: 10.1109/GUCON.2018.8675063.