Bidirectional Electric Vehicles Charger For Efficient Energy Management

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Abstract

The large number of electric vehicles (EV) in the global markets in near future implies that the engineering community must develop bidirectional charger system that would allow efficient charging/discharging process in a safe manner. In an EV charger system, several on-board electronic control units must operate in a synchronized manner when connected to the power grid. The bidirectional EV charger should be able to satisfy some major grid constraints including power quality, harmonic rejection, active and reactive power flow control. In this work we present a design of a smart grid compatible electric vehicle battery charger.

Introduction

Renewable energy sources are not equally available at all places and at all times. Energy storage such as Electric Vehicle, depicted in Fig.1, is seen as one of the suitable solution to most of the existing challenges in the smart grid. It can supply more flexibility and balancing to the grid, providing a back-up to intermittent renewable energy sources.
Locally, it can improve the management of the distribution networks, reducing costs and improving efficiency.

Fig.1- Electric Vehicles

In this work we implement a high-efficiency bidirectional DC-DC converter with low circulating current and Zero-Voltage Switching (ZVS) characteristic. We have simulated the bidirectional charger system under different conditions.

Methods

The system was modeled on Matlab Simulink. On the grid-side, as shown in Fig.2, a voltage source control is employed for AC system bus voltage and the DC-link voltage. On the EV-side, as seen in Fig.3, constant-current and constant-voltage control mechanisms are used for charging and discharging control with respect to the state of charge (SOC) of the battery.

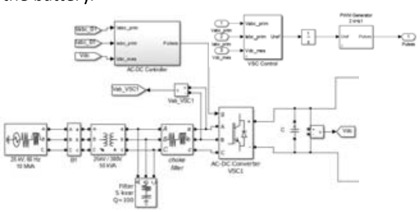


Fig.2- Real-time simulink model for the AC-DC side

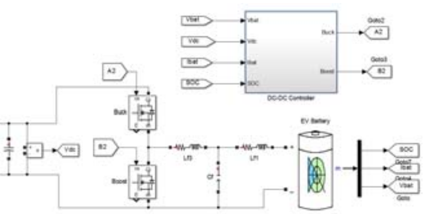


Fig.3- Real-time simulink model for the DC-DC side

We propose an EV charger which includes a high-efficiency bidirectional DC-DC converter, shown in Fig.4 with low circulating current and its Zero-Voltage Switching (ZVS) characteristic improving the overall charger operational behavior.

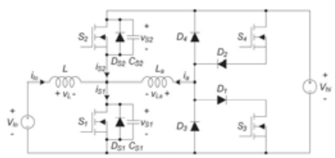


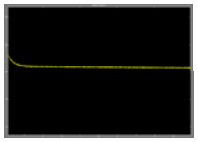
Fig.4- Bidirectional dc–dc converter

Simulation Results

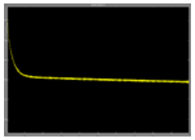
The purpose of the simulation is to test the performance of the proposed charger in both Grid-to-Vehicle and Vehicle-to-Grid scenarios.

Discharging Scheme

The discharging process is under a stable rated battery current and we show the results within 10 seconds in Fig.5.



Battery Current



Battery Voltage

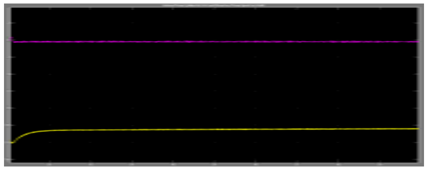
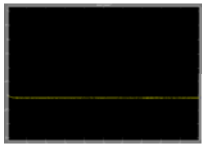


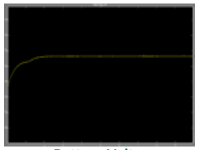
Fig.5- Active (Yellow) in kW and Reactive (Pink) in kvar Power

Charging Scheme

The charging scheme is still using CC/CV charging strategy and we show the results within 10 seconds in Fig.6.



Battery Current



Battery Voltage

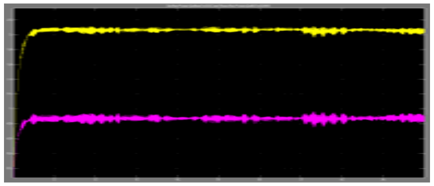
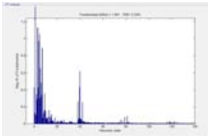


Fig.6- Active (Yellow) in kW and Reactive (Pink) in kVAR Power

In the entire charging and discharging process, all the parameters work under expected condition. The DC-Link voltage is maintained at the expected value of 680V and the THD of the discharging process is around 2.54% which shows a good stability in Fig.7.



Total Harmonic Distortion (THD)

DC-Link Capacitor Voltage

Fig.7- Parameters showing performance of the charger

Conclusions

As the results showed, the bidirectional power flow of the Electric Vehicle connected to the Grid will be easily controlled by sending a control signal to the AC-DC converter. In the charging process, the real power is positive and in the discharging process, it became negative, showing clearly the flow direction. Moreover, the constant DC-Link voltage and the low level of THD throughout the simulation period shows well stability.

Future Work

- Proposed charger is able to provide any specifics active and reactive into the grid by controlling the fire angle from the AC side.
- Nonlinear loads based on modern power electronics require advanced converter solutions in harmonic suppression and power quality regulation.
- In smart grid, the charger could be controlled by a remote controller providing the power flow in accordance to the grid needs.

References

[1] Jae-Won Yang and Hyun-Lark Do, "High-Efficiency Bidirectional DC–DC Converter With Low Circulating Current and ZVS Characteristic Throughout a Full Range of Loads", IEEE TRANSACTIONS ON INDUSTRIAL ELECTRONICS, VOL. 61, NO. 7, JULY 2014.
[2] KE BAO, "Battery Charge And Discharge Control For Energy Management In EDV And Utility Integration", University of Alabama, Alabama, June 2012.

Hypothesis

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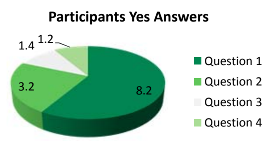
Step 1



	Mean	SD	P value
Age	37	+/- 4.25	.001
Weight	165 lbs.	+/- 35	n/a
Height	67 in.	+/- 12	n/a

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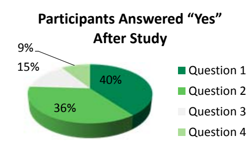

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DC capacitor link Voltage

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