BI-DIRECTIONAL CHARGER CIRCUIT AND ITS APPLICATIONS

Danush Tumkur Ravishankar & McCleve Paul-Gerald Joseph
College of Engineering and Computer Science, Syracuse University ,Syracuse NY 13244

ABSTRACT

Conventional electrical power transmission and distribution system are operated for the simple one-way transportation from remote and large power plants to consumers, but the system is just about to change, to satisfy some emerging needs. Electric Vehicle (EV) is seen as a suitable solution to most of the existing problems as it also presents a reduction of the amount of CO2 emission leading to a cleaner environment. One of the scenario is the EV's battery can be charged when the demand is less and be used to help the grid during peak demand hours maintaining the stability of the system. We designed a smart grid compatible electric vehicle battery bidirectional charger. The control strategy of the charger fulfills the IEEE Standards, demanding or injecting a balanced and sinusoidal into the grid minimizing the losses in the power flow. Simulation and experimental results are showed and we aim to develop a detailed mechanism of control to enhance the efficiency and lifespan of a Wind farm.

CONTACT

Danush Tumkur Ravishankar
Syracuse University, Electrical Engineering Department
Email: dttumkur@syr.edu
Phone: 315-4450-3917

INTRODUCTION

In today's world the non-renewable sources of energy are running out and the need for renew- able sources of energy has increased drastically. The increase in oil prices and the need for reducing the amount of CO2 emission are also major factors in encouraging the search for environment friendly and renewable energy sources. The Solar,Wind and Hydel energy are being used to generate electric energy. But, these renewable sources are not available equally at all places and at all times. Hybrid Electric Vehicle is a viable answer to most of the existing problems because of some of its advantages over its competitors :

1) The energy storage capacity of the batteries are increasing everyday. With the introduction of Li-Pol(Lithium ion polymer batteries) there has been a major change in electric vehicle industry.
2) The charging circuit can be so designed fro these vehicles such that the batteries can also give power back to the grid.
3) The cost for fuel is more than the cost for electricity required to travel the same distance.
4) These electric vehicles are environment friendly as the emission of waste gases due to fuel combustion is greatly reduced.

By using the bi-directional charger circuit we can charge the batteries at periods when the demand is less and the charged batteries can help the grid in handling demand in peak hours and also maintain the the stability of the grid. In this way the rechargeable battery can also function as a renewable source of energy throughout its lifecycle. We have designed a bi-directional charger with high efficiency DC-DC convertor and wireless controller.

METHODS

The bi-directional charger circuit consists of 3 important operations, they are 1) AC-DC conversion 2) DC-DC conversion and 3) DC-AC conversion.

The AC-DC and DC-DC conversion is controlled by the PWM signals generated by Arduino. The control signals cause the necessary switching action for the conversions to take place.

The DC-DC conversion in the forward direction performs the buck operation and in the reverse direction it performs boost operation. This convertor regulates the DC voltage.

The charger circuit has been simulated on I-Circuit and P-Spice. The detailed block diagram of the bi-directional charger is shown in **Figure 1**.

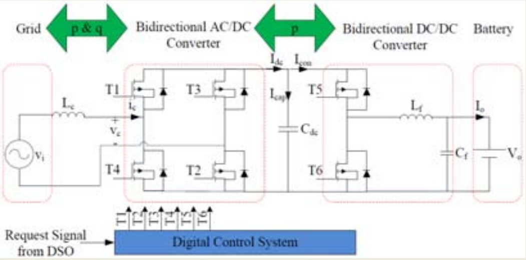

Figure 1. Functional Digram of Bi---directional Charger

The circuit diagram of AC-DC convertor and DC-DC convertor are shown in **Figure 2** and **Figure 3.** The necessary switching sequence for the proper functioning of the convertors is shown in Table 1 and Table 2. Figure 3 is an efficient DC-DC convertor for performing Buck-Boost operation.

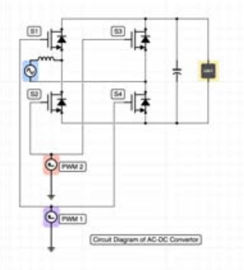

Figure 2. AC-DC Convertor

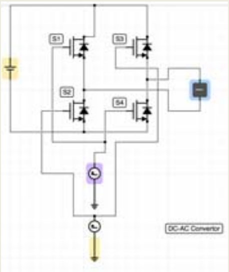

Figure 3. DC-AC Convertor

MODE	S1	S2	S3	S4	Vdc
I	ON	OFF	ON	OFF	0
II	ON	OFF	OFF	ON	+Vac
III	OFF	ON	ON	ON	-(-Vac)
IV	OFF	ON	OFF	ON	0

Table 1. Switching Sequence of AC-DC Convertor

MODE	S1	S2	S3	S4	Vdc
I	ON	OFF	ON	OFF	0
II	ON	OFF	OFF	ON	Vdc
III	OFF	ON	ON	OFF	-Vdc
IV	OFF	ON	OFF	ON	0

Table 2. Switching Sequence of DC-AC Convertor

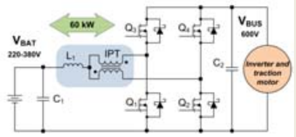

Figure 4. Block Digram of DC-DC Convertor [2]

The control signals are produced by Arduino. The controller receives the current sensor readings base on which it makes the decision on the direction of flow of current. The Arduino also has the capability to make large computations using grid related information. The Arduino is also capable of controlling wireless communication between various components of the circuit. Figure 5 shots a topology where the vehicle to grid

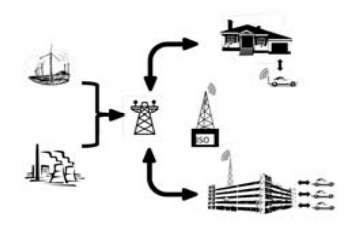

Figure 5. Implementation of Vehicle to Grid technology [3]

SIMULATION RESULTS

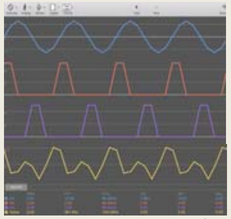

Figure 6. AC-DC Convertor Waveforms

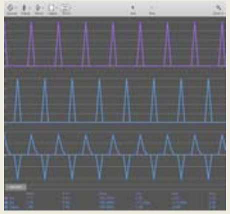

Figure 7. DC-AC Convertor Waveforms

Vac (Input) in volts	Vdc (Output) in volts
5	3.551
60	55.250
120	111.48
230	213.5

Table 3. AC-DC Convertor output voltage readings

Vdc (input) in volts	Vac (output) in volts
5	3.439
60	30
120	60
230	115

Table 4.DC-AC Convertor output voltage readings

The simulation for the bi-directional charger circuit were done using I-Circuit and the reading for different input values were tabulated. The above results depict the proper functioning of the bi-directional charger circuit. The readings obtained from the experimental setup concurs with the simulation results. The buck-boost operation of the DC-DC convertor is also verified.

CONCLUSIONS

The basic functionality of the charger circuit has been verified experimentally and by simulation. As a part of our future work we plan to reduce the harmonics by optimizing the filter design and we also aim at making the controller wireless and capable of controlling several charger circuits at the same time. This would result in a more cost effective and secure means of controlling the charger circuit. This charger circuit can also be used to control the functioning of the wind farms. The Arduino can control the wind turbine speed to maintain the wind turbine for efficient power generation and to keep the turbine components within designed speed and torque limits. We are presently working on analyzing whether look-up tables would be more efficient than computation procedure for control of wind turbine speed.

REFERENCES

[1] "A Bi-directional Battery Charger for Electric Vehicles Using Photovoltaic PCS Systems"Gyu-Yeong Choe*, Jong-Soo Kim*, Byoung-Kuk Lee*, Chung-Yuen Won*, Tea-Won Lee** * Sungkyunkwan University, 300, Cheoncheon-dong, Jangan-gu, Suwon-si, Gyeonggi-do, Korea ** Samsung Electro-Mechanics, 314 Maetan-3-dong Yeongtong-gu Suwon City Gyeonggi-do, Korea

[2] " High power density DC-DC converter with SiC MOSFETs for electric vehicles",Calderon-Lopez, G. ; Power Conversion Group, Univ. of Manchester, Manchester, UK ; Forsyth, A.J.

[3] Cvetkovic, I.; Thacker, T.; Dong Dong; Francis, G.; Podosinov, V.; Boroyevich, D.; Wang, F.; Burgos, R.; Skutt, G.; Lesko, J.; , "Future home uninterruptible renewable energy system with vehicle-to-grid technology," Energy Conversion Congress and Exposition, 2009. ECCE 2009. IEEE, vol., no., pp.2675-2681, 20-24 Sept. 2009.