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A Fuzzy Logic Based Controller for the Bidirectional Converter in an Electric Vehicle

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Abstract: ***Many technologies are focusing on the Electric Vehicles to grow in a big way to reduce the oil consumption and the carbon emmissions levels across all over the world in the near future. However there are many hindrance factors like the price of Li-ion batteries, charging infrastructure and charging methods are affecting the growth of EV's. Understanding these issues, a two stage basic converter popularly known as Bidirectional DC-DC converter is proposed for Grid-2-Vehicle, Vehicle-2-Grid, Vehicle-2-Home applications and leads to the efficient Energy Management Systems. The Bidirectional Converter uses an independent control using Fuzzy logic controller at each mode of power conversion stage. By using this unique feature, the Electrical Vehicle battery able to work in charging mode and discharging mode efficiently. In addition, this converter uses less number of components, with good operating efficiencies and most economical. The entire system has been developed using MATLAB-Simulink software.***

Keywords: Bidirectional Converter, ANFIS controller, Electric Vehicle

I. INTRODUCTION

From the developments of semiconductor technology the power electronic engineers made reliable products with the use of solar energy (or) renewables. Name a few, DC-DC converters are Buck/Boost chopper, Buck-Boost etc. are considered as classical converters. These converters provides basic knowledge and leads to the development of interleaved converters and Bidirectional converters. One of the popular applications like battery charging system with solar energy for domestic purpose (or) commercial purpose using classical converters gives desired output voltages, however, the operating efficiencies are very less. In addition, the switching losses are quite high, and thus less reliable.

In comparison with the performance of operating efficiencies of classical converters, the bidirectional converters are fairly good and more reliable in power sharing at all modes. The bidirectional converter distributes the energy between the grid to load, electric vehicles and vice versa. Popularly, the interfaces between Vehicle-to-Grid (V-2-G)/Grid-to-Vehicle (G-2-V) and also Vehicle-to-Home (V-2-H) can be developed with load balancing and active power regulation. Also a very few converters shown the improvement of battery performance in EV's. Still, the battery continues to be a major concern across all segments of EV's. With the two stage topology, bidirectional converters plays an important role in efficient utilization of electrical energy between batteries and vehicle/load [1-4]. The Bidirectional converter typically a two stage topology, which includes a DC-AC rectifier (stage I) and an isolated DC-DC converter (stage II) with LC filter. The block diagram of Bidirectional converter is shown in the figure **Error! Reference source not found.**, with control block. The low cost bidirectional DC-DC converter for V-2-G, G-2-V and V-2-H consists of a series LC resonant circuit is included in the circuit, thus further minimizes the ratings and employs zero switching. The paper is organized as follows: section II, the Electric Vehicle Battery Technologies are presented, the mode of operation of Bidirectional converter is explained in section III, the ANFIS Controller and the system specifications are presented in section IV, the MATLAB-Simulink and finally, the results and observations are concluded.

II. ELECTRIC VEHICLE BATTERY TECHNOLOGIES

Early 1900s was considered as best time for EVs in the transportation sector, as the usage of EVs was increased to double that of Natural gas and gasoline based fuel cars. But, by 1920 due to constraints and issues like weight, more charging time, runs for shorter distance and less rated capacity and due to this the EVs manufacturers are halted. However, the Internal Combustion Engine (ICE) engines took over the entire transportation sector and took the automobile market growth. From the last 3 decades, the applications of batteries used for electronic devices like laptops, mobiles etc. However, the batteries used for EVs are different and handle power upto tens of kWh with compact size, less weights and with affordable prices to the consumers. Since their invention, extensive research efforts and provided the various advanced battery technologies suitable for EVs and DC microgrids. The classification of batteries used for Evs by various automobile manufacturers are shown in the table I.

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The Nickel Metal Hydride (NiMh) type battery have low internal resistance and used for high currents drawn applications. The Lithium Ion (Li-Ion) batteries are environment friendly with high energy density [5-10].

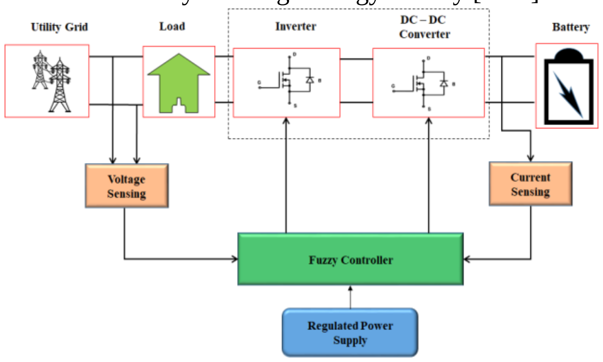

Fig.1 Block diagram of the proposed research

Recent market study has inferred the integration of EV batteries with the power grid in future. This comes as an appreciation to the development in the research of EVs and Micro grids. The proper integration of EVs with renewables improves the system optimization and voltage profile.

Basically power engineers and researchers need to know the basic chemistry of the various batteries used for EVs, and key parameters like energy density, specific energy, power density, cost, durability etc. The batteries are operated in a decentralized mode of operation in the case of microgrids and adjusts to local load to achieve the objectives of Demand Side Management (DSM). In addition, the EV battery modeling needs to interface the power electronic converter design, battery management system and system level studies. Depending on the operating conditions, i.e, temperature, charging and discharging current, State of Charge (SoC) etc, the performance of a battery varies, and thus its service time varies [11-16].

Battery charging/ Infrastructure is the highest priority for most of the automobile manufcturers, reserchers and utilities. The battery should offer its energy for home appliences, since most of the EVs are used for a limited duration. Using various international standards like Society of Automative Engineers (SAE), The Electric Drive Transport Association (EDTA), Japanese EV Association are universally available on EV's performance for better safety and service/maintenance.

Table I: Types of Batteries used in EV's

Company	Country	Vehicle Type	Battery technology
GM	USA	Chevrolet Volt	Li-ion
Ford	USA	Escape, Fusion, MKZ HEV	Nickel Metal Hydride (NiMh)
Toyota	Japan	Prius, Lexus	Nickel Metal Hydride (NiMh)
Honda	Japan	Civic, Insight	Nickel Metal Hydride (NiMh)
Hyundai	South Korea	Sonata Ltd	Lithium Polymer
BMW	Germany	BMW X6	Nickel Metal Hydride (NiMh)
Mitsubishi	Japan	i-MiEV	Li-ion
Nissan	Japan	Altima	Nickel Metal Hydride (NiMh)
Tesla	USA	Roadster (Spider,2010)	Li-ion

III. FUZZY NETWORK LOGIC CONTROLLER

The error function and change in error has five Gaussian functions i.e.,

$e(t)=\{PS_e, PB_e, ZE_e, NS_e, NB_e\}$ and $\frac{de(t)}{dt}=\{PS_e, PB_e, ZE_e, NS_e, NB_e\}$ and the values are in the range of {-1,1}. The membership function rules are shown in the tables **Error! Reference source not found.** and **Error! Reference source not found.**.

Table II: Fuzzy logic control Rules for Error unit

Error(e)	PS_e	PB_e	ZE_e	NS_e	NB_e
PB_e	PB_e	PB_e	PB_e	PS_e	ZE_e
PS_e	PB_e	PB_e	PS_e	ZE_e	NS_e
ZE_e	PS_e	PB_e	ZE_e	NS_e	NB_e
NS_e	ZE_e	PS_e	NS_e	NB_e	NB_e
NB_e	NS_e	ZE_e	NB_e	NB_e	NB_e

Table III: Fuzzy logic control Rules for Change Error unit

Change in Error($\frac{de(t)}{dt}$)	PS_e	PB_e	ZE_e	NS_e	NB_e
PB_e	PB_e	PB_e	PB_e	PS_e	ZE_e
PS_e	PB_e	PB_e	PS_e	ZE_e	NS_e
ZE_e	PS_e	PB_e	ZE_e	NS_e	NB_e
NS_e	ZE_e	PS_e	NS_e	NB_e	NB_e
NB_e	NS_e	ZE_e	NB_e	NB_e	NB_e

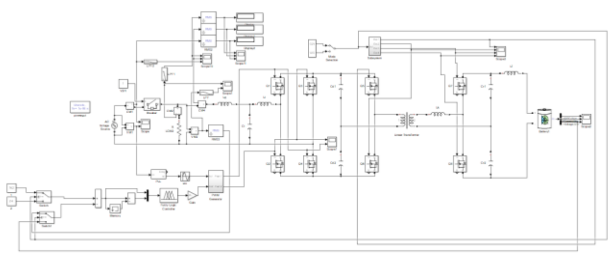

Fig.2 DC-DC bidirectional converter

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IV. MODE OF POWER TRANSFER

The DC-DC Bidirectional Converter circuit is operated in 2 modes, based on the power demand and shown in Fig. **Error! Reference source not found.**.

A . GRID-TO-VEHICLE MODE (CHARGING MODE)

The Fig.3 shows the State of Charge of Li-ion battery of the Bidirectional converter system and charged to 80%, through the rectifier which is connected to the grid.

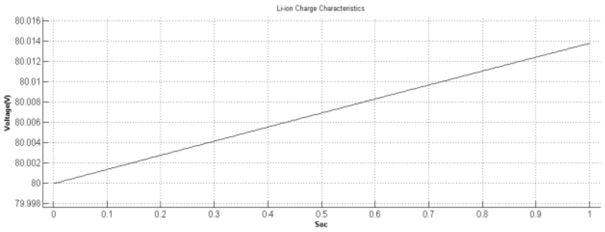

Fig.3 State of charge of li-ion battery of the bidirectional converter system

The Fig. **Error! Reference source not found.** shows the battery current of Li-ion battery of the Bidirectional converter system.

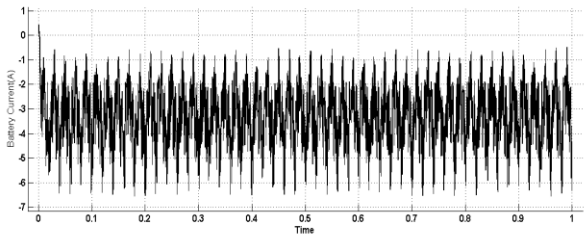

Fig.4 Battery current of Li-ion battery of the Bidirectional converter system

The Fig. **Error! Reference source not found.** shows the battery voltage of Li-ion battery of the Bidirectional converter system, the Fig. **Error! Reference source not found.** shows the grid voltage of 218V the Bidirectional converter system

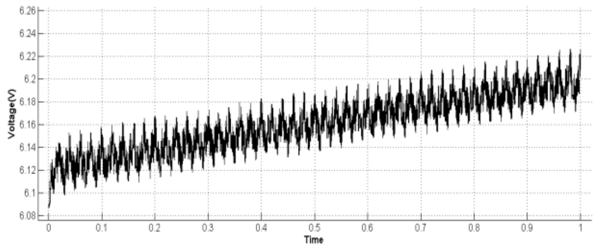

Fig.5 Battery voltage of Li-ion battery of the Bidirectional converter system

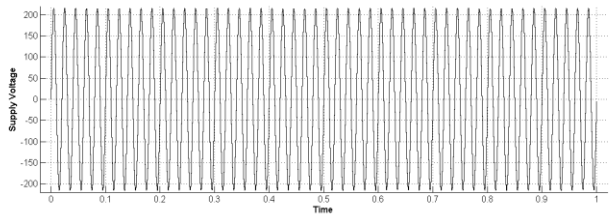

Fig.6 Grid voltage of 218V the bidirectional converter system

B. VEHICLE-TO-GRID MODE (DISCHARGING MODE)

The Fig. **Error! Reference source not found.** shows the State of Discharge mode of Li-ion battery in the system and discharged from 80%.

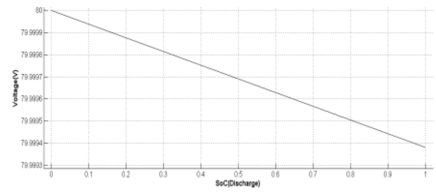

Fig. **Error! Reference source not found.** State of discharge mode of Li-ion battery

The Fig. **Error! Reference source not found.** shows the battery current of Li-ion battery of the Bidirectional converter system and the Fig. **Error! Reference source not found.** shows the battery current of Li-ion battery of the Bidirectional converter system.

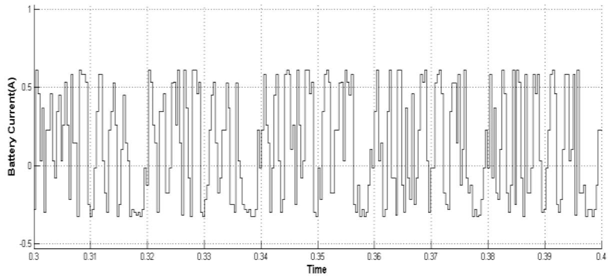

Fig. **Error! Reference source not found.** Battery current of Li-ion battery of the Bidirectional converter system

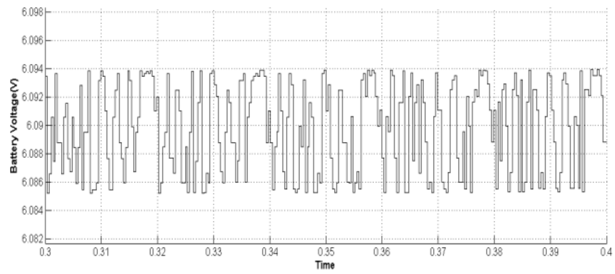

Fig. **Error! Reference source not found.** Battery current of Li-ion battery of the Bidirectional converter system

The following Fig. **Error! Reference source not found.** & **Error! Reference source not found.** shows the load current and voltage across the load (resistor) respectively. However, the harmonics present in the Battery current will be further reduced using filtering methods.

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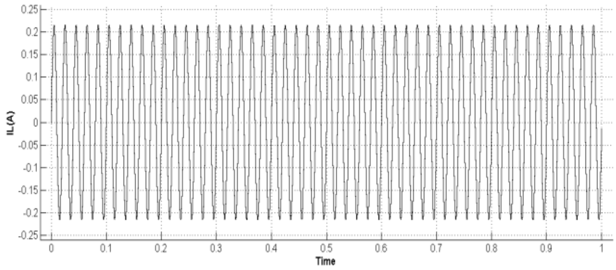

Fig. 10 Load current across the load

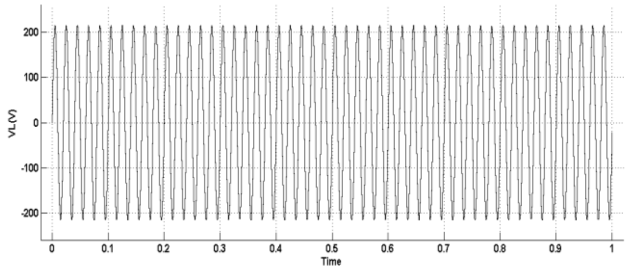

Fig.11 Load voltage across the load

V. CONCLUSIONS

The Fuzzy logic control network is simple and with auto tuning feature makes easy in regulating or controlling the flow of energy from Grid to Vehicle or vice-versa. The Fuzzy logic control with Sugeno model is used for the flow of energy on both ends and the same is simulated in the MATLAB Simulink. In addition, this control logic is easily programmed and the PWM pulses are generated with the logic control. In this paper, the proposed model of Bidirectional DC-DC converter is simulated and the flow of energy is efficiently transferred for the applications V-2-G, V-2-H or G-2-V and the various waveforms are shown for the analysis.

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