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Performance of Bidirectional Chopper and Multi-Operational Inverter with Hybrid Energy System

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Abstract- In this paper a power electronic interface circuit is proposed for application of battery electric vehicle, the battery is been charged by using a Photovoltaic cell and a Wind Energy Conversion System. The power flow in the battery vehicles is managed by implementing the power electronic interfaces. The interface comprises of the integration of Bidirectional Chopper, DC link, and Multi Operational Inverter for the conversion of AC to the system. The overall performance of the system is enhanced with the help of the Power Flow controller. The simulation has been analyzed by using MATLAB/SIMULINK and a hardware prototype is implemented.

Index Term- Bidirectional Chopper, Battery, Multi-operation Inverter, Motor, PV, Wind.

I. INTRODUCTION

Due to the impending global energy crisis such as urban pollution and energy issues the automobile manufacturers have been pushed to introduce a new generation of battery electric vehicles that leads to clean vehicle technologies. Renewable energies, the clean energy technology are of different types they are Photovoltaic, Wind, Geothermal, Hydro, Biomass etc. among these PV and Wind are chosen because the resource used for convention is efficient thus the clean energy is obtained .MPPT system can be utilize to track the maximum power corresponding to the flow of the power generation. Now-a-days the battery electric vehicles are becoming an alternative to internal combustion engine vehicles due to the improvement in the field of battery technologies. The battery electric vehicles have to be recharged with electricity from the grid. Thus the battery electric vehicle reduces the energy dependences and provides for nil local emission and fuel efficient vehicles. Indeed, the battery electric vehicles have a few challenges to overcome such as limited driving range, long charging time, battery lifetime, power electronics performance, and high initial rate. The power electronic interface utilizes a low voltage energy source and energy storage system (such as fuel cells, battery systems, and super capacitors) which is interfaced with an electric motor in electric vehicles. In the conventional system, Z-source inverters (ZSI) have been used due to its boosting capability and it saves component cost by utilizing a single conversion stage.

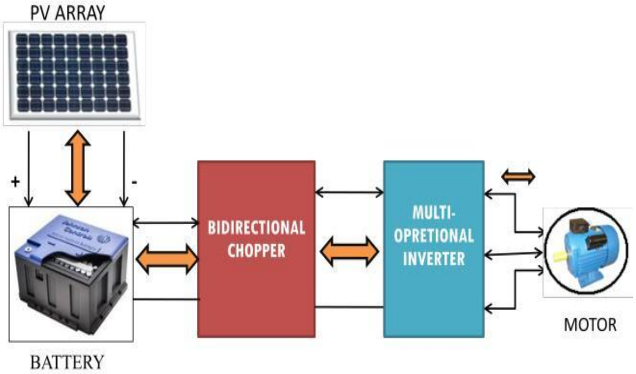

Fig. 1 Conventional Diagram of the Battery Electric Vehicles

ZSI has major drawbacks such as difficult control, high current and voltage stresses, limited boost ratio and less consistency. Owing to the disadvantages in ZSI, the interface is implemented in vehicles which mainly focus on improving the efficiency, reliability, cost, and size. The conventional structure of the PEI utilizes two different kinds of converters and one kind of inverter.

These are given as follows:

1) Bidirectional DC/DC converter, which interfaces an LV energy storage systems (such as batteries or super capacitors) to the DC-Link;

2) Bidirectional AC/DC converter, which is used to connect the battery to the grid during charging or discharging operating modes;

3) Bidirectional DC/AC inverter, which is used to transfer the energy from the DC-link to the traction motor [such as three-phase induction motor (IM)].

The integration of DC/DC converter and DC/AC inverter together forms hybrid electric vehicles which play a vital role in the growth of high efficiency and high performance in electric vehicles.

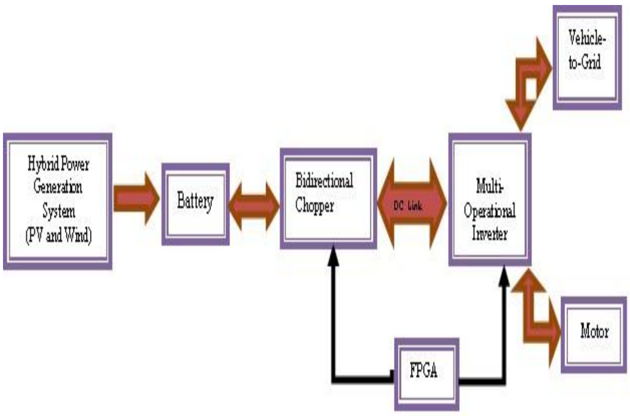

Fig. 2 Proposed Block Diagram of the BEV Power Train

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The proposed topology interface utilizes on-board battery charger which can be recharged from any outlet available at home garages that increases the feasibility of vehicles.

Table I. Summary Of The Operating Modes

Operating Mode	PEI	
	MULTI-OPERATIONAL INVERTER	BIDIRECTIONAL CHOPPER
Mode1	Three Phase DC/AC Inverter	Boost Mode
Mode2	Three Phase AC/DCPWM Rectifier	Buck Mode
Mode3	Single Phase AC/DCPWM Rectifier	Buck Mode
Mode4	Single Phase DC/AC Inverter	Boost Mode

The proposed PEI incorporates the features of the bidirectional chopper and multi-operational inverter which can realize all operating modes for electric vehicles, such as grip mode, regenerative mode, and charging/discharging modes from the ac grid. The control strategy is PWM current control based PI compensators for charging/ discharging modes and FPGA controller is used. The major concern of the interface are efficiency, reliability, size of the passive components, compact system, high power factor, low total harmonic distortion (THD), and input/output ripples.

II. BIDIRECTIONAL CHOPPER

The bidirectional chopper along with energy storage has become a promising option for many power related systems, together with hybrid vehicle, fuel cell vehicle, and renewable energy system. It reduces the cost and improve good organization, but also improves the performance of the system. In the electric vehicle applications, an back up energy storage battery absorbs the regenerated energy fed back by the electric machine. With its capability to reverse the direction of the current flow, and in this manner power, the bidirectional DC-DC converters are being increasingly used to achieve power transfer between two DC power sources in either direction. The bidirectional chopper is a double sided power flow in which the switch should carry the current on both directions. It is generally executed with a unidirectional semiconductor power switch such as power MOSFET or IGBT in parallel with a diode.

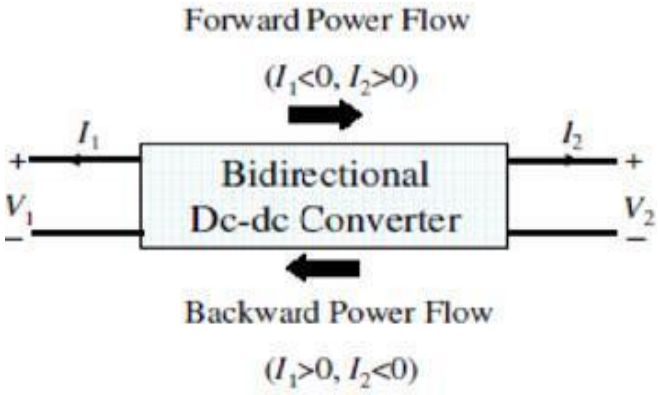

Fig. 3 Illustration of Bidirectional Power Flow

The bidirectional chopper can be categorized into buck and boost type. The buck type is to have energy storage located on the high voltage side, and the boost type is to have it located on the low voltage side. It is characterized by a current fed or voltage fed on one side which is shown in Fig4.

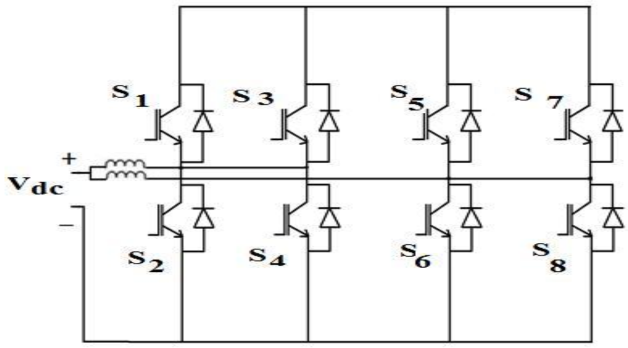

Fig. 4 Bidirectional Chopper

The bidirectional chopper consists of eight switches connected with anti-parallel diodes and source impedance. The chopper has the ability to reduce the size of the passive components (such as inductors and capacitor), and to reduce input/ output EMI filters by means of increasing the frequency of inductor current ripple and the output voltage ripple without increasing the switching frequency . The input and output of the circuit is DC and hence it is a DC/DC chopper. The supply voltage from the battery is fed to the bidirectional chopper now the chopper acts in boost mode in order to supply the load, which in turn operates in mode 1 and mode 4.similarly the power flow is taken place from the load to the battery .now the chopper acts in buck mode, which in turn operates in mode 2 and mode 3.

III. MULTI-OPERATIONAL INVERTER

The multi-operational inverter is the only means to transfer the energy from/to the traction motor during traction and braking modes or to transfer the energy from/to the ac grid during charging and discharging modes. In mode1 and mode 2 the switches from S1 to S6 are conducted. These switches acts as three phase DC/AC inverter and three phase AC/DCPWM rectifier. In mode 3 and mode 4 the switches S3,S5,S7 and S8 are conducted which acts in single phase DC/AC inverter and single phase AC/DCPWM rectifier, where in the other switches such as S1,S4,S6 and S2 are in unity.

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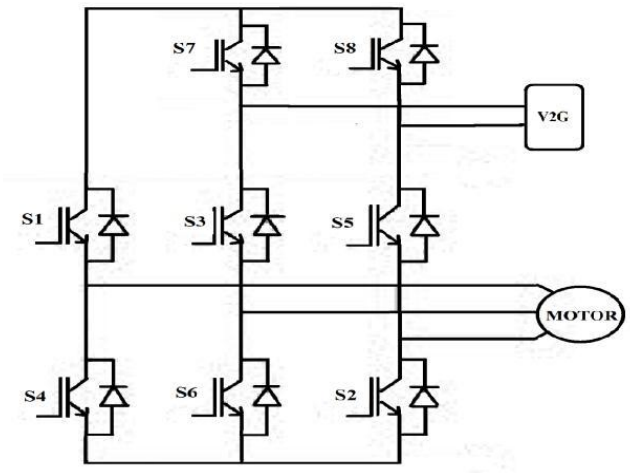

Fig. 5 Multi-Operational Inverter

IV. POWER FLOW CONTROLLERS

The power flow controller performs the operation of power flow management where four modes are implemented as follows

- Mode 1: Power flows from Source to Load.
- Mode 2: Power flows from Load to Source.
- Mode 3: Power flows from Grid to Source.
- Mode 4: Power flows from Source to Grid.

In this paper, FPGA (Field Programmable Gate Array) controllers are been used namely. A field-programmable gate array (FPGA) is an integrated circuit designed to be configured by a designer after manufacturing hence “field-programmable”. The FPGA configuration is normally specified using a hardware description language (HDL), similar to that used for an ASIC. FPGAs contain programmable logic components called “logic blocks”, and a series of command of reconfigurable interconnects that allow the blocks to be “wired together” somewhat like many logic gates that can be inter-wired in different configurations. Logic blocks can be configured to execute versatile combinational functions, or just simple logic gates like AND and XOR. In most FPGAs, the logic blocks also contain memory elements, which may be easy flip-flops or more whole blocks of memory. The prototype is controlled by FPGA controller.

V. PHOTOVOLTAIC ARRAY

The PV cell acts very much like a battery when the sun is shining on it. It has a fairly steady voltage (Vdc) but the current (Idc) varies based on the intensity of the beam. Voltage and current are needed to produce power. A PV panel is made up of a series of PV cells. The term “series” means that the cells are connected in a way that allows the voltage to increase at a desired operating level. If you took apart a 9V battery you would see they are made up of six small 1.5V batteries wired in “series.” The same method is used for PV panels. There may be tracking arrays or modules or flat arrays. A tracking array is defined as one which is always kept mechanically perpendicular to the sun array line so that all times it intercepts the most isolation. Such array must be physically movable by a suitable prime mover and are generally considerably more complex than fixed arrays. A fixed array is generally oriented east west and tilted up at an angle approximately equal to the latitude of the site. The PV cells are used to charge the battery.

There are basically 4 modules of PV panels

- Less than 12V – used for powering or charging small devices like radios and cell phones.
- 12V panels/36 cells – used mainly to charge 12V battery systems (this has been implemented in this paper).
- 24V panels/72 cells – used mainly to charge 24V battery systems.
- Greater that 24V – used for large battery systems and grid-tied systems.

VI. WIND ENERGY SYSTEM

Wind energy change system converts the kinetic energy of the wind into electrical energy or other form of energy. Wind energy system is very much power produces and also highly preferred than conventional source of the power. India plays a leading grade in the global wind energy marketplace, but it is still not use its full wind possible, which is far from the beat condition. The major components of a typical wind energy conversion system include a wind turbine, generator interconnection equipment and control system. Wind turbine can be designed are two types they are variable speed and constant or fixed speed operation. Variable speed wind turbine system produce more power compare than constant speed system. The power electronic converter may organize the turbine rotation speed to get the maximum possible power by means of a maximum power point tracking (MPPT) strategy. It is also possible to avoid more than the nominal power if the wind speed increases by means of Power Control mechanism of Wind Turbines. Therefore every wind turbines are designed with some power control mechanism. In wind energy system using gear box, its increase the speed of the machine.When electric-vehicle move and then rotate the wind turbine and produce the power.

VII. SIMULATION RESULTS

The performance of the proposed topology simulation has been analyzed by using MATLAB/Simulink software.

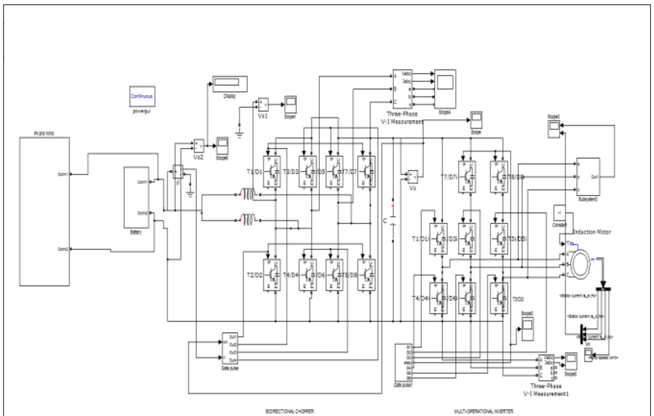

Fig. 6 MATLAB Model of the Proposed System

The MATLAB model Fig 6. Shows the complete layout of the proposed topology. Different modes are involved in this circuit with help of the controller according to the Load's (Motor) demand.

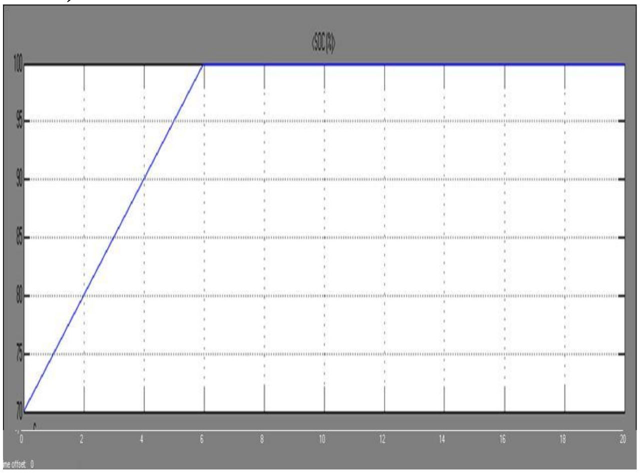

Fig. 7 Battery Charging Mode

The charging of battery due to the power flow from the load to source is shown in Fig 7. Here the battery charging state is suddenly raised to a peak level and after some period the battery's state of charge is maintained at a constant level. The battery's state of charge in which 70% is taken as its initial level. Here the battery is suddenly raised to the maximum level to 100% at the time duration of 6ms and thereby it is maintained constant.

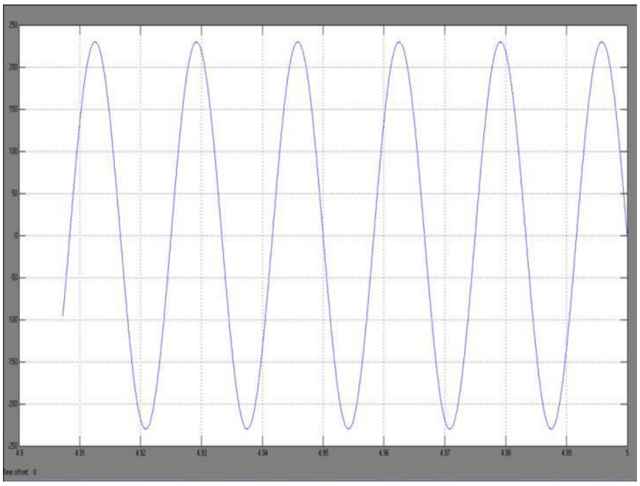

Fig. 8 AC Output Waveform

The flow of power from source to the load for a voltage of about 230 V as an output is described in Fig 8.Due to this power flow the load gets operated.

VIII. CONCLUSION AND FUTURE WORK

In this paper, a power electronic interface has been proposed for electric vehicle for effective performance. The proposed power electronic interface combines the features of the bidirectional chopper and Multi-operational inverter. Different control strategies are designed to verify the performance of topology during different operating mode. It should be pointed out that the FPGA Controller and PI Compensator have been used .As it is clear from the simulation results, this interface can reduce the current and voltage ripples, can improve the efficiency, reliability and compact size, increased battery lifespan. Finally, the simulation and experimental results have demonstrated that the interface has been successfully realized and it assures for high performance in electric vehicle compared to other topologies. In future this system is to be implemented on the DSP platform.

REFERENCES

1. Omar Hegazy, Ricardo Barrero, Joeri Van Mierlo, Philippe Lataire, Noshin Omar, and Thierry Coosemans "An Advanced Power Electronics Interface for Electric Vehicles Applications" IEEE transactions on power electronics, vol. 28, no. 12, Dec 2013.
2. C. C. Chan, A. Bouscayrol, and K. Chen, "Electric, hybrid, and fuel-cell vehicles: Architectures and modeling,"IEEE Trans Veh.Technol.,vol.59, no. 2, pp. 589–598, Feb. 2010.
3. A. Emadi, Y. J. Lee, and K. Rajashekara, "Power electronics and motor drives in electric, hybrid electric, and plug-in hybrid electric vehicles," IEEE Trans. Ind. Electron, vol. 55, no. 6, pp. 2237–2245, Jun. 2008.
4. Y.-J. Lee, A. Khaligh, and A. Emadi, "Advanced integrated bidirectional AC-DC and DC-DC converter for plug-in hybrid electric vehicles," IEEE Trans. Veh. Technol., vol. 58, no. 8, pp. 3970–3980, Oct. 2009.
5. O. Hegazy, J. Van Mierlo, and P. Lataire, "Analysis, modeling, and im-plementation of a multidevice interleaved DC/DC converter for fuel cell hybrid electric vehicles," IEEE Trans. Power Electron., vol. 27, no. 11, pp. 4445–4458, Nov. 2012.
6. Y.-C. Kuo, T.-J. Liang, and J.-F. Chen, "Novel maximum-power-pointtracking controller for photovoltaic energy conversion system" IEEE Trans. Ind. Electron., vol. 48, no. 3, pp. 594–601.
7. Jung-Min Kwon, Kwang-Hee Nam and Bong-Hwan Kwon, "Photovoltaic Power Conditioning System With Line Connection" IEEE Trans. Ind. Electron., vol. 53, no. 4, pp.1048-1054.
8. C. Gordillo, E. Rodriguez, A. Lopez, J. Hurtado, J. Diaz, N. Vazquez "Battery Charger with Maximun Charge Tracking Current for PV Systems" Trans. Inst. Electr. Eng. Jpn., vol. 121-D, no. 12, pp. 1263–1269, 2001.
9. Alireza Khaligh,, and Serkan Dusmez, "Comprehensive Topological Analysis of Conductive and Inductive Charging Solutions for Plug-In Electric Vehicles"IEEE trans on vehicular technology, vol. 61, no. 8, oct 2012.
10. C. C. Chan, Alain Bouscayrol, and Keyu Chen, "Electric, Hybrid, and Fuel-Cell Vehicles: Architectures and Modeling"IEEE Trans on vehicular technology, vol. 59, no. 2, feb 2010.
11. U. K.Madawala, P. Schweizer, and V. V. Haerri, "Living and mobility— "A novel multipurpose in-house grid interface with plug-in hybrid BlueAngle," in *Proc. IEEE ICSET*, Nov. 24–27, 2008, pp. 531–536.
12. S. Labatt and R. R. White, *Carbon Finance: The Financial Implications of Climate Change*. Hoboken, NJ: Wiley, 2007.
13. K.Wang, C. Y. Lin, L. Zhu, D. Qu, F. C. Lee, and J. S. Lai,"Bidirectional dc/dc converters for fuel cell systems,"in Proc.IEEE Power Electron.Transportion,1998,pp.47-51.
14. G. R. Walker and P. C. Sernia, "Cascaded DC–DC converter connection of photovoltaic modules," *IEEE Trans. Power Electron.*, vol. 19, no. 4,pp. 1130–1139, Jul. 2004.
15. T. Shimizu, O. Hashimoto, and G. Kimura, "A novel high-performanceutility-interactive photovoltaic inverter system," *IEEE Trans. Power Electron.*,vol. 18, no. 2, pp. 704–711, Mar. 2003.
16. L.Chang,R.Doraiswami, T. Boutot and H.Kojabadi, "Development of a Wind Turbine Simulator for Wind Energy Conversion System,"IEEE CCECE2000 Canadian Conference on Electrical and Computer Engineering, Halifax, Canada, May 2000.
17. H.J. Chiu and L.-W. Lin, "A bidirectional DC-DC converter for fuel cell electric vehicle driving system,"IEEE Trans. Power Electronics., vol.21,pp.950-958, jul. 2006.
18. A. Mullane and M. O'Malley, "The inertial response of Induction machine-based wind turbines," *IEEE Trans. Power Syst.*, vol. 20,no. 3, pp. 1496–1503, Aug. 2005.

19. A. Tapia, G. Tapia, J. X. Ostolaza, and J. R. Saenz, “Modeling and control of a wind turbine driven doubly-fed induction generator, ”*IEEE Trans. Energy Conv.*, vol. 18, no. 2, pp. 149–204, June 2003.
20. M. Chinchilla, S. Arnaltes, and J. L. Rodriguez-Amenedo, “Laboratory set-up for wind turbine emulation,” *IEEE ICIT Conf.*
21. *Proc.*, vol. 1, 2004, pp. 553 - 557.

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