ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

Performance of DC Motor Drive Application for Parallel Current Sharing Boost Converters by Using Fuel and Battery Energy Sources

Srivastavayi Srujana
M.Tech Student,
Department of EEE,
Krishnaveni Engineering College For Women
Narasaraopet, A.P, India.

Dr.Y.Sreenivasa Rao
Principal,
Department of EEE,
Krishnaveni Engineering College For Women
Narasaraopet, A.P, India.

ABSTRACT:
The hybrid source consists of fuel cells (FCs) stack, battery packs and Ultra capacitor (UC) modules. In the proposed parallel energy sharing control, each source is connected to a DC bus via power electronics converters. The proposed optimization is based on the knowledge of individual boost parameters. Every loss through the structure are modeled by equivalent resistors. Using an accurate online estimation of those resistors, the losses through each individual converter can be determined. Then, a new current sharing scheme is defined aiming to maximize the global efficiency of the overall structure. A basic analysis of each component of the investigated system is presented. The main objective of this paper is to manage the energy transfer from the PEMFC stack to the DC bus based on wide high efficiency range. A battery pack is used for reducing the size of the stack and thus the cost, with by which regenerative braking is also achieved. In order to testify the nonlinear V-I characteristic curve of the PEMFC system experiments have been carried out. The performance of the overall system in steady state is studied via simulation in MATLAB/SIMULINK software.

Key-Words:- ***Fuel cell, battery, Ultra capacitor, Hybrid source, Fuel cell hybrid vehicle, Energy management control and Parallel energy-sharing control.***

I. INTRODUCTION

Due to the rapid escalating of gasoline prices, depletion of fossil fuels and environmental concerns, most of the automotive industries have intensified in the development and commercialization of minimum-and-zero emission vehicles. Electric vehicles (EVs) powered by battery is one of the early approaches to green technology. However, the major problems that are normally associated with the Battery Electric Vehicles (BEVs) are its relatively short travel journey and long charging period. Due to these barriers, one of the alternative solutions in replacing of battery as primary energy source in the EV is to use of FC generator. This type of vehicle is known as fuel cell electric vehicle (FCEV). Application of FCs in vehicle is one of the promising solutions to provide a high energy efficient, quiet, less pollutant and electric vehicle with longer driving range (as long as the fuel supply is available). The Polymer electrolyte membrane Fuel Cell (PEMFC) is commonly utilized in the FCEV due to its relatively small size, light weight and simple structure [1-3]. PEMFC generates electricity through the chemical reaction between hydrogen and oxygen. Hence, the by-products from it contains of heat and water. However, there are problems when one tries to use FC alone to power the vehicle, such as its relatively short lifespan, poor dynamic response, difficulty during FC cold startup, high cost, and inability to capture of braking energy during vehicle deceleration or downhill [3- 5]. Moreover, peak power demand from the FC could lead to fuel starvation phenomenon and shorten its lifespan. For these reasons, hybridization of FC with energy storage units (ESUs) is necessary in order to overcome these problems as well to reduce the vehicle size and cost [4]. ESUs can compose of the battery modules, UC modules or combination of both (combined ESUs).The comparative study performed in [3,4,8,9] indicate that FC-battery-UC hybrid vehicle could lead to a more practical solution, higher fuel economy and extends battery lifespan. From the literatures, most of the proposed energy management strategies applied in the FC hybrid source are of series configurations[3,4,9].In series configuration, the energy dense source is used to charge on the power dense source, and the power dense source is used to regulate the DC bus and to response of peak power demand.

This paper proposed a parallel energysharing control for the FCEV combining of FC generator, battery and UC modules. The aim of this paper is to discuss on the control structures and the design of the proposed parallel energy-sharing algorithm. With parallel energy-sharing control, the load demand can be simultaneously provided by all energy sources, however, with different contribution depending on the characteristics of energy sources and the control strategy. In other words, parallel energy control can provide higher degree of energy sharing and greater output power during steady state. ESUs can be used to compensate power requirement once the load demand is larger than the maximum power available from the FC generator. Consequently, the overall volume of the hybrid sources can be downsized and optimized. The battery, on the other hand, can be operated in a narrow charge-discharge cycle and work in idle condition during steady state provided that the based power demand can be fulfilled by the FC.

For vehicle applications, the internal combustion engine (ICE) has lower total efficiency (13.8%) in respect to FC (21.7%) [4]. Also, the FC produces lower exhaust emissions and has lower operating noise in comparison to conventional ICEs [5]. Load requirements change during drive in vehicles and since FCs have a slow dynamic response, auxiliary energy source is needed as it was mentioned above. In our system an FC stack and a battery pack are included. This configuration has many advantages. The auxiliary energy storage device can supplement the FC Stack when the vehicle demands high power. As a result, FC Stack can be sized to cover a great rate of the maximum power and so the overall cost of the vehicle is reduced. Another advantage is the recovery of regenerative braking energy and the storage in the auxiliary source [6, 7]. The main drawback of a FCEV is the lack of availability of hydrogen which could be over by producing hydrogen from wind turbines and photovoltaic cells [8] or by reforming hydrocarbon such as natural gas. In this work the configuration and the modeling of the drive system for a light FCEV are presented. The main energy source is provided by a PEMFC stack. Among several kinds of FCs, PEMFC has relatively high power density, smaller size, lower operating temperature and easy start. In this work, the secondary energy source is a battery pack, which is connected to the DC bus via a suitable converter which will

II. PROPOSED SYSTEM

Energy management is one of the most important factors to ensure the optimization in efficiency, dynamic performance as well as reliability of a FCHV. This is true especially with the utilization of combined ESUs (battery and UC). In order to optimally used of each source and avoid them from hazardous, the proposed algorithm in this paper is developed based on the characteristics of vehicle load components, FC, UC and battery. These are discussed as follows. - FCHV load components can be categorized into two types: constant load and transient load. Constant load consists of based load (on-board electric load and air conditioning), rolling resistance, aerodynamic drag and gravitational load during uphill or downhill. These loads are almost constant and they should be supplied from the FC. On the other hand, transient load is associated with the power needed during acceleration, deceleration or braking. These loads cause a quick power transient response and should be compensated by the energy buffer or storage units. - Fuel cell (FC) shows a slow transient response and has a relatively high internal resistance. In addition, FC system has the disadvantages of slow start-up and this often cited as a major opposition to the use of FC in domestic vehicle especially with the used of fuel reformer [10]. However, FC is able to supply the power continuously as long as the reactants are available. Hence, it could functions as a power generator in the hybrid source by constantly supplying the average or required steady state power. The power flow during this mode is as shown in Fig. 1(a). Depends on the speed of vehicle and state-of-charge (SOC) of ESUs, the FC is used to charge on them while they are in low energy content. A power slope limiter is needed to avoid FC from any peak transient response which could effect to a permanent damage on it (FC starvation phenomenon). - Ultracapacitor (UC) has a very high capacitance density and able to provide a large amount of power (high specific power) within a relatively short period (low specific energy). Moreover, UC is a robust device. It has an extremely long lifecycle, low maintenance and low internal resistance. So, during the design of energy management system, the UC can functions as main energy buffer during peak power transient period. Nevertheless, UC is known to have a relatively low energy density and fast self-discharge characteristics. Application of UC solely as ESU in the FCHEV may face vehicle start-up problem after it has been left for a number of weeks. Therefore, during the start-up stage, power must generally come from energy dense sources such as battery. - Battery has an advantage of high specific energy but relatively low in specific power. The power response is faster than FC, but slower than UC. Furthermore, battery has a limited lifespan (300-2000 cycles) [10,11]. It depends on a lot of factors such as: types of the battery, depth of discharge cycles, discharge rate, cell operating temperature, charging regime, number of overcharge and others. Hence, to optimize the lifespan of battery, it is recommended that the battery current slope must be limited within a safety range in order to reduce the peak transient stress toward it. So, the peak power response can be come from the UC. As discussed early, the main power during the start-up stage must mostly comes from the battery as depicted in the Fig. 1(c).

The DC bus voltage control loop is used to control the DC bus output voltage to its fixed reference value. A current reference (Iload) signal is generated by the DC bus voltage controller and becomes the main source of the three inner current control loop references namely the FC, the battery and the UC current loops. The switching frequency of the PWM current loops is set to 10kHz, hence with this, the cut-off frequencies for the voltage and current control loops are selected as 10 Hz and 1k Hz respectively. In order to limit the slope of the current references for the battery and FC within their safe values, low pass filters with time constants $\tau 1$ and $\tau 2$ ($\tau 2 < \tau 1$) are used respectively. The final value of current reference for the UC is obtained by subtracting the reference current generated by the DC voltage loop with the output current from battery and FC; this is to ensure that only the UC current reference contains the demanding peak transient elements of the load current reference. To enable the battery to operate in a narrow charge-discharge cycle, the battery current reference is subtracted with the FC output current. By doing so, the peak power demand from the FC is avoided and at the same time only the FC will supply the continuous steady state power.

In Proposed systems, the bidirectional dc-dc converter along with energy storage has become a promising option for many power related systems, including hybrid vehicle, fuel cell vehicle, renewable energy system, industries and so forth. The proposed converter is designed in the manner of closed loop control. Because closed loop control have advantages than open loop control. By using modern controller, we can obtain a high output voltage and high gain by controlling the duty cycle of switches. So it reduces switching current, frequency, high output voltage. We can reduce the heat loss, which can increase the switches life span. Not only reduces the cost and improves efficiency, but also improves the performance of the system.

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

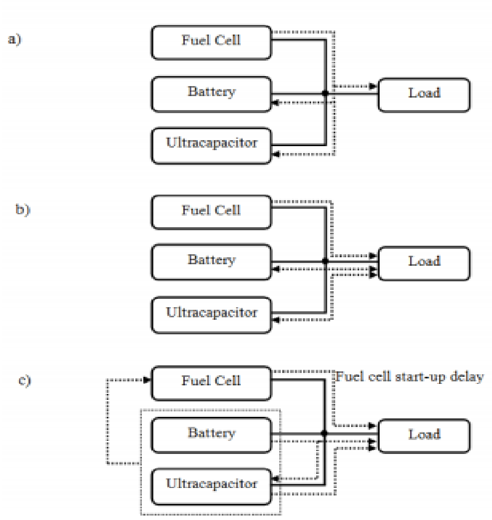

Fig. 1 Mode of power flow in the proposed hybrid system: a) during steady state, b) during transient, c) during start-up (solid arrow indicates of main power flow, dotted arrow indicates of secondary power flow)

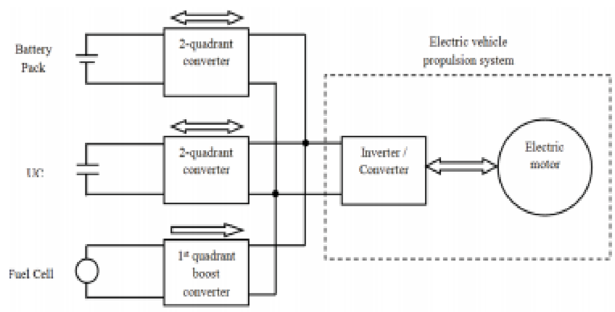

Fig. 2 Proposed parallel energy sharing system

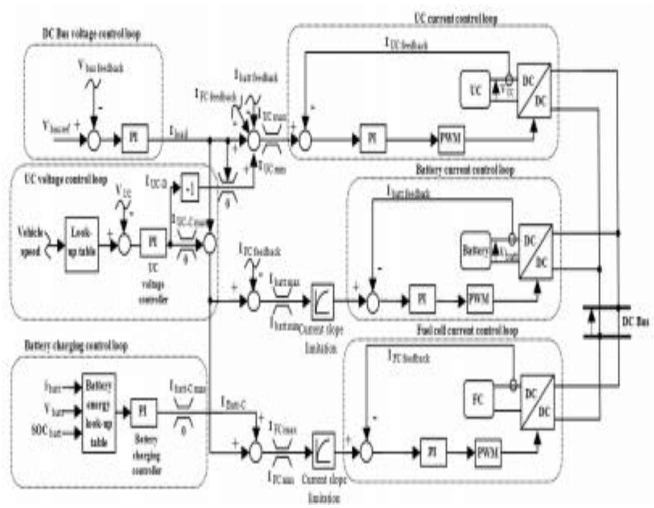

Fig. 3 Proposed parallel energy-sharing control for the FC-battery-UC hybrid system

UC is used mainly for two reasons: to provide the peak important to ensure that the UC is always ready to provide the power requirement during acceleration and to absorb vehicle peak power as well as to absorb the braking power. For this kinetic energy during regenerative braking. It is therefore reason, the SOC of the UC is made dependent on the vehicle speed such that the available space of energy storage in the UC is proportional to the vehicle kinetic energy. For instance, if the vehicle is moving fast (i.e. large kinetic energy), more room is made available in the UC for regenerative braking and vice versa. Thus the UC voltage is given by equation (1).

$$V_{UC}(v) \leq \sqrt{V_{UC,max}^{2} - \frac{M}{C_{UC}} v^{2}} \quad (1)$$

In (1), VUC is the terminal voltage of the UC, VUC,max is the allowable maximum voltage of the UC, M is the mass of the vehicle, v is the speed of vehicle and CUC is the capacitance of the UC. To ensure that the UC always has an adequate energy from the battery and FC for vehicle acceleration, UC charging command (IUC-C) is added to the battery and FC current references. Conversely, UC need to be discharged to provide sufficient volume for the vehicle kinetic energy during regenerative braking. This can be realized by summing up the UC discharge command (IUC-D) to the UC current control loop. To avoid battery being charged by UC, the UC discharge command is limited to load current demand. In the proposed energy control system, battery is only charged by the FC and controlled through the battery charging control loop.

A simple charging method is implemented to charge on the battery, which is based on constant current-constant voltage (CCCV) method. It is assumed that the initial SOC of the battery can be obtained based on its open-circuit terminal voltage [10]. The battery charging command (IBatt-C) is generated by adding output of the battery voltage controller loop with the current reference of FC current control loop.

III. CIRCUIT DESCRIPTION

Converter operation: The bidirectional dc-dc converter shown in Figure1 is operated in continuous conduction mode for forward motoring and regenerative braking of the dc motor. The MOSFETs Q1 and Q2 are switched in such a way that the converter operates in steady state with four sub intervals namely interval 1(t0-t1), interval 2(t1- t2), interval 3(t2-t3) and interval 4(t3-t4). It should be noted that the low voltage battery side voltage is taken as V1 and high voltage load side is taken as V2. The gate drives of switches Q1 and Q2 are shown in Figure 3. The circuit operations in steady state for different intervals are elaborated below. Interval 1(t0-t1): At time t0, the lower switch Q2 is turned ON and the upper switch Q1 is turned OFF with diode D1, D2 reverse biased as shown in Figure 2(a). During this time interval the converter operates in boost mode and the inductor is charged and current through the inductor increases. Interval 2(t1-t2): During this interval both switches Q1 and Q2 is turned OFF. The body diode D1 of upper switch Q1 starts conducting as shown in Figure 2(b). The converter output voltage is applied across the motor. As this converter operates in boost mode is capable of increasing the battery voltage to run the motor in forward direction. Interval 3(t2-t3): At time t3, the upper switch Q1 is turned ON and the lower switch Q2 is turned OFF with diode D1, D2 reverse biased as shown in Figure 2(c). During this time interval the converter operates in buck mode. Interval 4(t3-t4): During this interval both switches Q1 and Q2 is turned OFF. The body diode D2 of lower switch Q2 starts conducting as shown in Figure 2(d). Converter design: The bi-directional converter is designed based on the input supply voltage and output voltage requirement to drive the electric vehicle at desired speed. The converter power topology is based on a half bridge circuit to control the dc motor

IV. RESULTS AND DISCUSSIONS

Simulations as well as experiments are carried out to verify the viability of the proposed method. The simulation is carried out using of MATLAB/Simulink simulation program. Fig. 4 shows the laboratory-scale experimental set-up used to verify the proposed scheme. In the experi ment, the battery module is composed of 4 series connected 12V, 45AH calcium-calcium batteries. The UC used in the experiment is a BMOD0165 EO48 BO1 BOOSTCAP from Maxwell with 165F capacity and 48V voltage rating. Due to the unavailability of the FC generator during the experiment, its behavior is emulated by a dc power supply HP6675A with an output voltage set to 48V. The DC bus voltage is regulated at 80V and a closed-loop torque control DC motor drive rated at 0.25hp 120V 3000 r.p.m. is used to represent vehicle propulsion system.

The control algorithm is implemented using dSPACE DS1104 controller board with an overall sampling period of 100μs. Fig. 5 and 6 show the simulation and experimental results during an ideal start-stop cycle, respectively. The DC motor is accelerated from stand still to a steady speed speed of 1300 rpm and then decelerated back to stand still. As can be seen from the figures, the simulation and experimental results are in close agreement. Initially, the battery is fully charged and the SOC of the UC is set at 87.5% (VUC =42 V). During acceleration, the peak current is mainly supplied by the UC followed by the battery and FC. This can be clearly seen from Fig. 7(a), which is closer look of Fig. 6 during acceleration. It can also be seen that the slope of the current drawn from the battery and FC are limited; depending on the setting of time constants $\tau 1$ and $\tau 2$ which effectively limit the rate of change of the reference current. During steady state speed, UC is discharged to make room for the braking power. Once the UC attained to its reference voltage, depending on the required power under steady state speed, FC supplies all the constant load power while the battery and UC operate in idle conditions. From Fig. 7 (b), when the DC motor decelerates, it can be observed that a sharp braking power was mostly recuperated by the UC followed by the battery (within a limited current slope). Subsequently, the battery and FC will charge the UC up to its reference voltage to ensure good dynamic response later during acceleration.

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

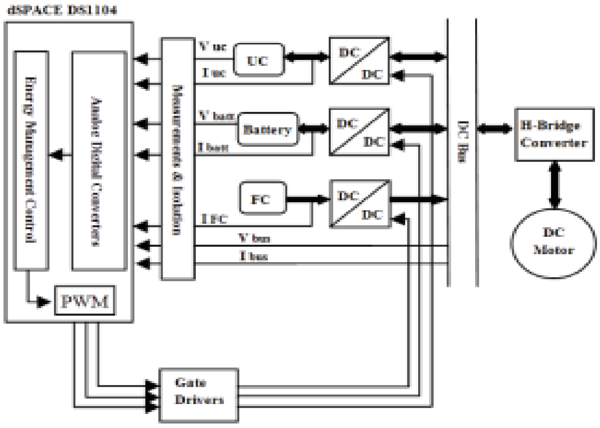

Fig. 4 Proposed implementation (a) Block diagram of the experimental set-up

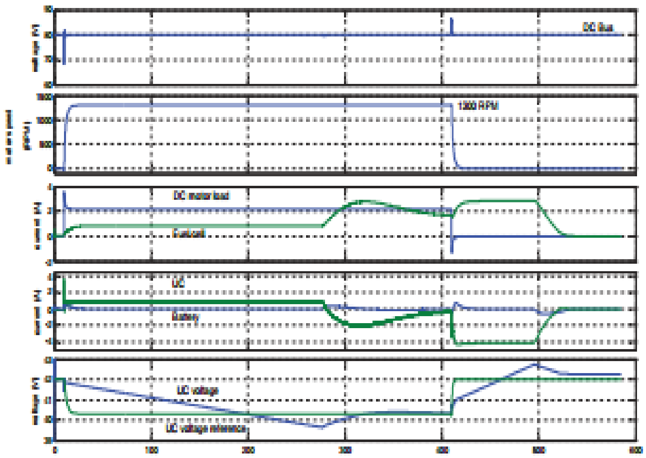

Fig. 5 Simulation results for an ideal start-stop cycle

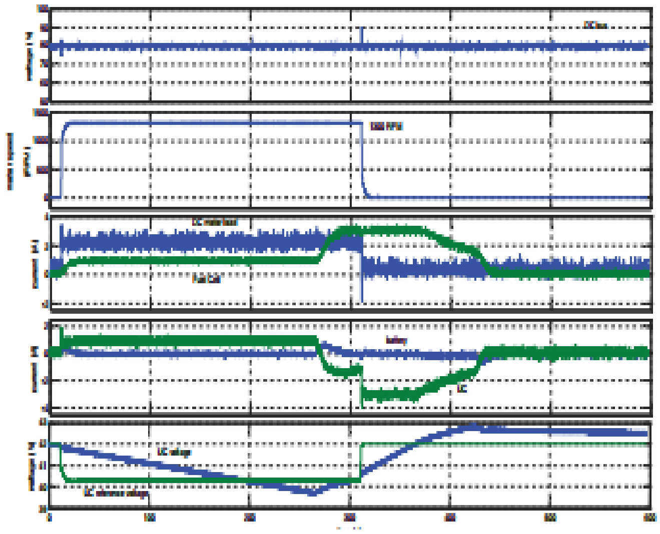

Fig. 6 Experimental results for an ideal start-stop cycle

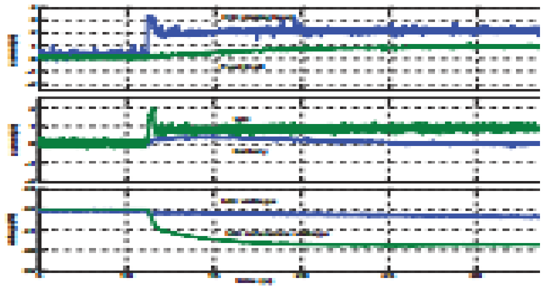

Fig. (a)

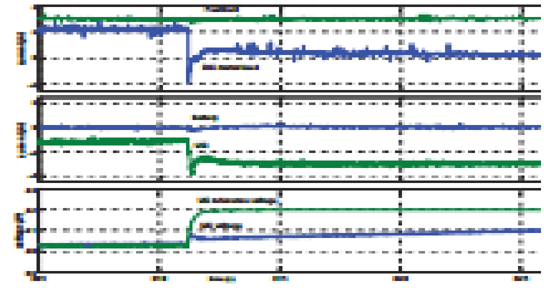

Fig. (b)

Fig. 7 a) Transient responses during motor acceleration b) Transient responses during motor deceleration (zoom in)

V. CONCLUSION

This paper mainly discusses on design and control structures for the proposed parallel energy-sharing containing FC generator, battery and UC. Through the proposed energy control algorithm, overstress toward FC and battery is avoided. Voltage of the UC is controlled accordingly to vehicle speed in order to ensure sufficient energy for vehicle acceleration and also adequate volume for vehicle braking. The proposed method does not guarantee perfect results in all situations, but provides a satisfactory energy management method in controling the overall FCHV system. The validity of the proposed energy control scheme is supported by simulation and experimental results under average and peak power response.

REFERENCES

[1]. J.-S. Lai and D. J. Nelson, “Energy management power converters in hybrid electric and fuel cell vehicles,” in Proc. IEEE Ind. Electron., Taipei, Taiwan, Volume 95,Issue 4, April 2007, pp. 766 – 777.

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

[2]. H. Tao, A. Kotsopoulos, J.L. Duarte, and M.A.M. Hendrix, "Multiinput bidirectional dc-dc converter combining dc-link and magnetic-coupling for fuel cell systems," in Proc. IEEE IAS, Hong Kong, China, Volume 3, Oct. 2005, pp. 2021 –2028.

[3]. H. Tao, J. L. Duarte, and M. A. M. Hendrix, "High-power threeport three-phase bidirectional dc-dc converter," in Proc. IEEE IAS, Manchester, UK, Sept. 2007, pp.2022 – 2029.

[4]. H.-J. Chiu, H.-M. Huang, L.-W. Lin, and M.-H. Tseng, "A multiple-input dc/dc converter for renewable energy systems," in Proc. IEEE ICIT, Hong Kong, China, Dec. 2005, pp. 1304 – 1308.

[5]. G.-J. Su, J. P. Cunningham, and L. Tang, "A Reduced-part, triplevoltage dc-dc converter for electric vehicle power management," in Proc. IEEE PESC, Orlando, FL, June 2007, pp. 1989 – 1994.

[6]. T. Mishima, E. Hiraki, T. Tanaka, and M. Nakaoka, "A new softswitched bidirectional dc-dc converter topology for automotive high voltage dc Bus architectures," in Conf. Rec. of IEEE VPPC, Windsor, UK, Sept. 2006, pp. 1 – 6.

[7]. H. Matsuo, W. Lin, F. Kurokawa, T. Shigemizu, and N. Watanabe, "Characteristics of the multiple-input dc-dc converter," IEEE Trans. Ind. Electron., Vol.51, No.3, June 2004, pp. 625-630.

[8]. Y. Hu, J. Tatler, and Z. Chen, "A bidirectional dc-dc power electronic converter for an energy storage device in an autonomous power system," in Proc. IEEE IPEMC, Xi'an, China, Volume 1, August 2004, pp. 171 – 176.

[9]. S. Jalbrzykowski, and T. Citko "A bidirectional DC-DC converter for renewable energy systems" in Bulletin of the Polish Academy of Sciences,Technical sciences Vol. 57, No. 4, 2009

[10]. H. Matsuo and F. Kurokawa, "New solar cell power supply system using a Boost type bidirectinal dc-dc converter," IEEE Trans. Ind. Electron., Volume IE-31, Issue 1, Feb. 1984, pp. 51 – 55.

[11]. H.-J. Chiu and L.-W. Lin, "A bidirectional dc-dc converter for fuel cell electric vehicle driving system," IEEE Trans. Power Electron., Volume 21, Issue 4, July 2006, pp. 950 – 958.

[12]. G. Chen, D. Xu, and Y.-S. Lee, "A family of soft-switching phaseshift bidirectional dc-dc converters: synthesis, analysis, and experiment," in Proc. the Power Conversion Conference, Osaka, Japan, Volume 1, 2-5 April 2002, pp. 122 – 127.

[13]. G. Chen, D. Xu, Y. Wang, Y.-S. Lee, "A new family of softswitching phase-shift bidirectional dc-dc converters," in Proc. IEEE PESC, Vancouver, British Columbia, Canada, Volume 2, June 2001, pp. 859 – 865.

[14]. H. Fan, D. Xu, "A family of PWM plus phase-shift bidirectional dc-dc converters,"in Proc. IEEE PESC, Aachen, Germany, Volume 2, 20-25 June 2004, pp. 1668 –1674.

[15]. P. Jose and N. Mohan, "A novel bidirectional dc-dc converter with ZVS and interleaving for dual voltage systems in automobiles," in Proc. IEEE IAS, Pittsburg, Pennsylvania, Volume 2, Oct. 2002, pp. 1311 – 1314.