EVS-25
Shenzhen, China, Nov 5-9, 2010

Design of Power System Control in Hybrid Electric Vehicle

Van Tsai Liu

Department of Electrical Engineering, National Formosa University, Huwei 632, Taiwan

E-mail: vtliu@nfu.edu.tw

Abstract

This paper proposes a design of power system control in the hybrid electric vehicle. It adopts the isolated DC/DC power converter as the front-end fuel cell and Lithium-ion battery to supply constant voltage. By micro-controller to detect the hybrid power output, and the low-pressure hydrogen storage temperature, and the adjustment of the power output ratio to provide the energy for loading balance. The results can obtain the overall performance of electric vehicle. It is important to avoid the excessive usage of hydrogen fuel which causes the phenomenon of storage tank freezing and fuel cell or Lithium-ion batteries abnormal situation. Display the working data of hybrid power system can achieve the capability of instant surveillance. For the loading under consideration, the fuel cell and Lithium-ion battery can supply stable voltage output. *Copyright Form of EVS25*.

Keywords: hybrid electric vehicle, fuel cell, push-pull converter, Lithium-ion *battery*

1 Introduction

Vehicles technology brings convenience in traffic for humans, but cause serious global warming, air pollution, depletion of oil resources and other issues. Therefore, the hybrid and pure electric vehicles is the most effective way to reduce emissions of carbon dioxide, which is about 45% of internal combustion engine vehicle emissions, or even non-exhaust emissions [1]. Electric vehicles system becomes effective solution to reduce air pollution and fossil fuel [2].

In recent years, power conversion system of fuel cell has been proposed. The fuel cell is used in electric vehicles, the most compelling reason is that fuel-cell electric vehicles are electric-drive vehicles as a source, not only will have no exhaust pollution, and can resolve the problem of depletion for oil stocks[3]. This structure of electric vehicle system is based on fuel cells for energy supply sources, but was limited by the fuel cell electrochemical reaction rate. Therefore, vehicles can not provide an instant start and climbing required output power, and the batteries or super capacitors as auxiliary power supply is used to provide a steady output for the load [4].

2 System structure

Based on hybrid power system and energy distribution is proposed hybrid electric vehicle system structure shown in figure 1 [5-9]. This article uses the fuel cell and lithium-ion battery as power sources, and fuel cell power generation process as : The low-pressure hydrogen storage bottles provides hydrogen, and through the appropriate hydrogen pressure regulating valve to adjust the pressure switch by the hydrogen fuel cell modules into the house with the oxygen is electrochemically converted. Fuel cells and lithium-ion batteries can not smooth voltage output in the load change, so must uses the power converter to output stable voltage for the motor-driven DC-wheel drive motor. About power distribution of control design for the output state that uses the A/D feedback circuits and pressure sensors to detect the fuel cell, Lithium-ion battery voltage and the hydrogen storage bottle pressure. After the micro-controller via judge that sends PWM signals to the power distribution circuit. The power converter controls the output load ratio of the energy, and completes the complex the overall design of power electric vehicles.

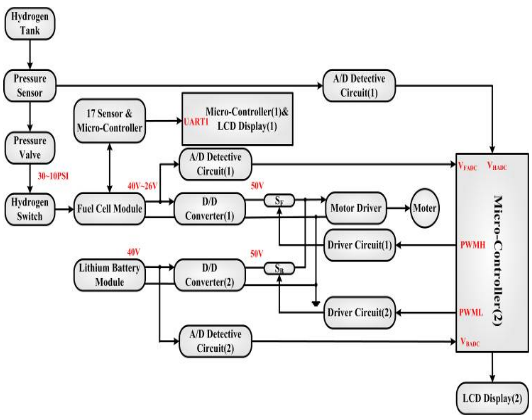


Figure 1: Block diagram of hybrid electric vehicle

3 Design of power converter

Figure 2 demonstrates the power converter is used for the full-bridge rectifier push-pull converter. The article uses KA3525 as a drive control IC to control the power switches (S1,S2) of the conduction and cut-off time respectively with two PWM output circuit. Dead time and frequency of the speed is series-parallel resistor and capacitor to control. The secondary side of isolated power conversion is used optocoupler feedback circuit. Ratio converter (CT) is used to detect currents flowing through the power switch, besides, protect the switch and prevent circuit overload. The circuit design is tally with specifications, such as Table 1.

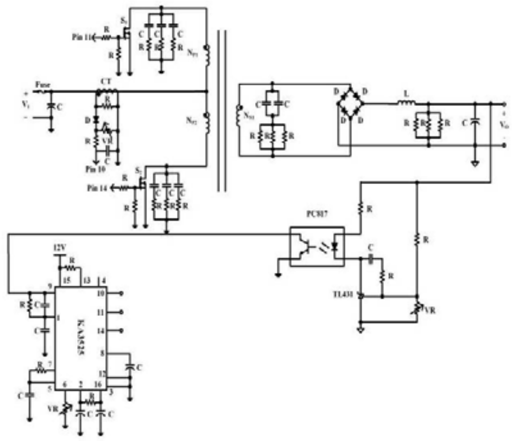


Figure 2: The circuit of push-pull converter

Table 1: Push-pull converter specification

Input voltage	DC 26V-40V
Switch frequency	50 kHz
Output voltage	DC 50V
Output current	12A

4 Design of complex power systems control

The hybrid electric vehicles will be considered for safe driving that depends on the electric power distribution systems. About hybrid power and stability control is proposed a power distribution system control structure shown in figure 3.This structure consists of two parts:

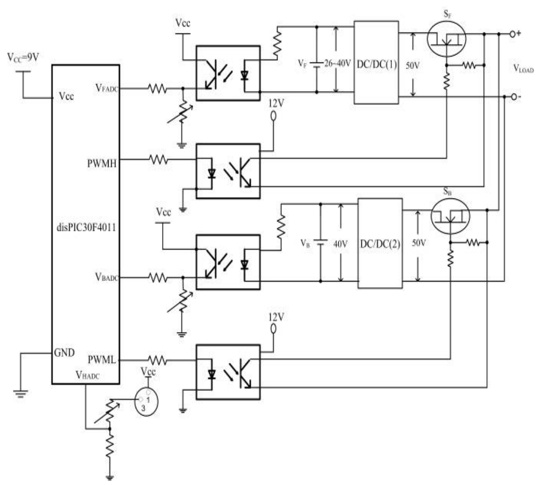


Figure 3: The structure of power distribution system

1. A/D detection circuit: Based on the protection of micro-controllers and A/D conversion values, which is used the optocoupler isolated as a complex dynamic system feedback. The main pressure sensor to detect the pressure of conversion values, moreover, the lithium-ion battery voltage and fuel-cell voltage is obtained to determine treatment by the micro-controller for the output energy distribution of control signals.
2. PWM driver circuit: The output control signals are not sufficient to drive power switches for the micro-controller. High current through circuits to reflux prevention of abnormal result, which give rise to burn for micro-controller. Therefore, the optically coupled driver circuit is used to reach power switch isolation amplified in this article.

This design of approach using the Microchip's dsPIC30F4011 in A/D, PWM and LCD display [10]. The main uses AD-based, and samples the output voltage in the fuel cell. Lithium-ion battery output voltage and pressure sensors convert voltage signals is as a control power distribution circuit of the PWM signal output. The signal determines the priority shown in figure 4. First the fuel cell is No.1 priority, the next is Lithium-ion batteries, and the last is the pressure sensor signal. Table 2 is based on the sampling that designed states of signal control that has the following five kinds of:

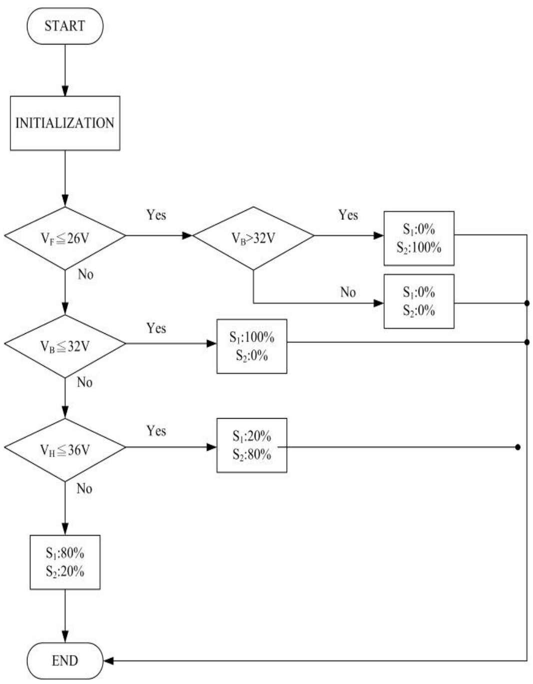


Figure 4: Block diagram of the energy control strategy for hybrid electric vehicle

1. If the fuel cell voltage is greater than 26V, the Lithium-ion battery voltage is greater than 32V, and the pressure sensor feedback voltage is greater than 36V: The fuel cell is controlled at 80% to output, and the Lithium-ion battery is at 20%.
2. If the fuel cell voltage is greater than 26V, the Lithium-ion battery voltage is greater than 32V, and the pressure sensor feedback voltage is less than or equal to 36V: The fuel cell is controlled at 20% to output, and the Lithium-ion battery is at 80%.
3. If the fuel cell voltage is less than or equal to 26V, and the Lithium-ion battery voltage is greater than 32V: The fuel cell is stopped to output, and the Lithium-ion battery is controlled to output at 100%.
4. If the fuel cell voltage is greater than 26V, and the Lithium-ion battery voltage is less than or equal to 32V: The fuel cell is controlled to output at 100%, and the Lithium-ion battery is stopped to output.
5. If the fuel cell voltage is less than or equal to 26V and the Lithium-ion battery voltage is less than or equal to 32V: The fuel cell and the Lithium-ion battery is stopped to output.

Table 2: The state of energy distribution

Normal State	$V_F > 26V$, $V_B > 32V$, $V_H > 36V$	S_F : 80%
		S_B : 20%
Lack of hydrogen State	$V_F > 26V$, $V_B > 32V$, $V_H \leq 36V$	S_F : 20%
		S_B : 80%
Fuel Cell Abnormal State	$V_B > 32V$, $V_F \leq 26V$	S_F : 0%
		S_B : 100%
Lithium battery Abnormal State	$V_F > 26V$, $V_B \leq 32V$	S_F : 100%
		S_B : 0%
Hybrid power Abnormal State	$V_F \leq 26V$, $V_B \leq 32V$	S_F : 0%
		S_B : 0%

5 Experiment Results

The input voltage and the output voltage waveform of the converter are shown in figure 5. This figure shows the non-pumping load conditions of fuel cells and lithium batteries, because the load current affects the output voltage level. Therefore, the power converter needs a stable output voltage for the load.

This article uses micro-controller to detect the fuel cell voltage. The Lithium-ion battery voltage and output pressure hydrogen storage bottle of hydrogen through the A/D feedback circuit to judge hybrid voltage output. Control signals decided the distribution of electrical energy in the system, and display distribution system state of the current power at work, as shown in figure 6-9.

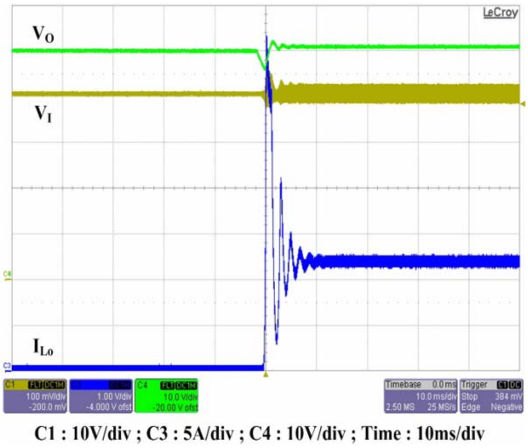
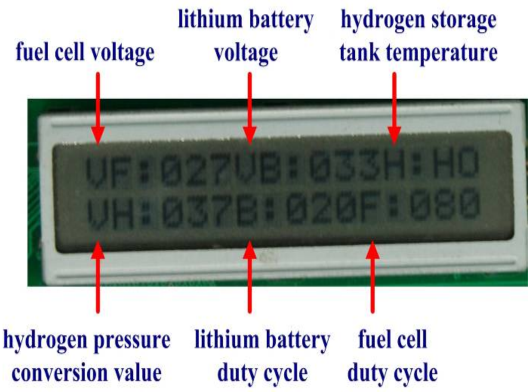
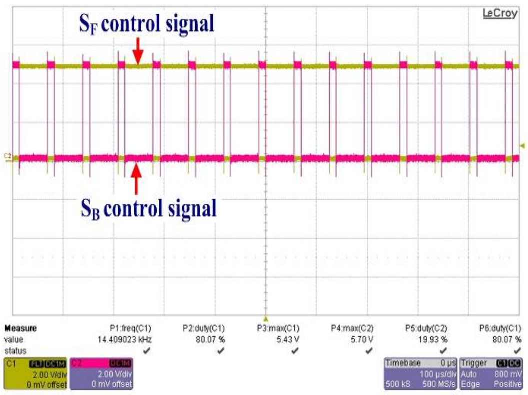


Figure 5: Input voltage, output voltage, and output inductor current waveforms. (Step change from 0 to 600W)

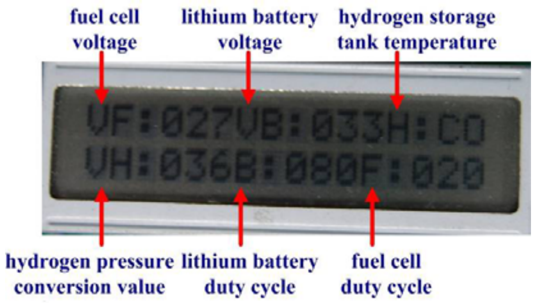


(a)

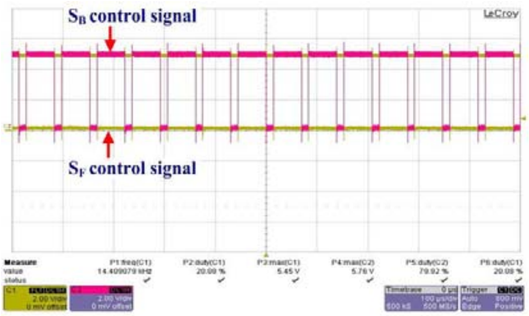


(b)

Figure 6: At normal state, (a) Power control signal (b) Status of display

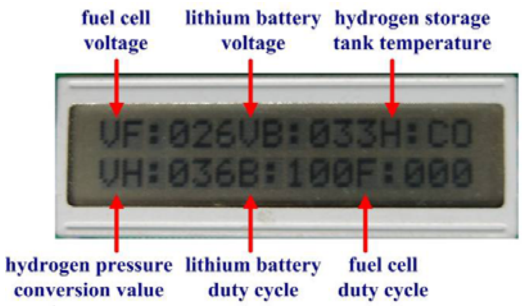


(a)

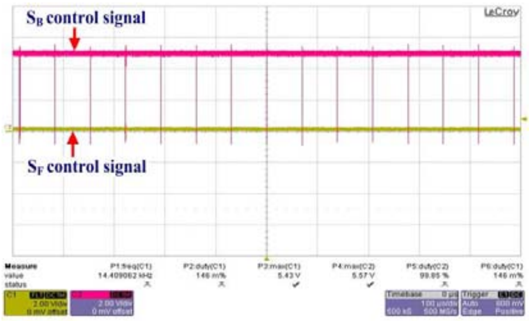


(b)

Figure 7: At hydrogen lack state, (a) Power control signal (b) Status of display

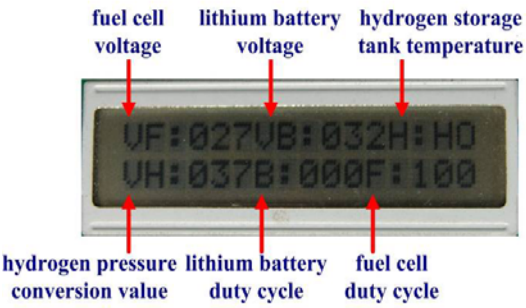


(a)

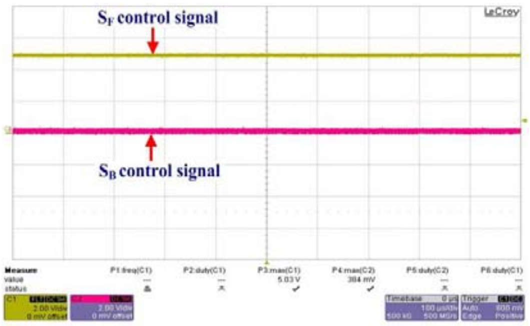


(b)

Figure 8: At fuel cell abnormality, (a) Power control signal (b) Status of display



(a)



(b)

Figure 9: At Lithium-ion battery abnormality, (a) Power control signal (b) Status of display

Figure 10 is the complete with the hybrid electric vehicle. At various loads and power status measure the fuel cell and the lithium-ion battery output power, as shown in figure 11-14. From the figure could discover that the fuel cell and lithium-ion battery power distribution status and the whole hybrid system are feasible.

Figure 10: Complete diagram of hybrid electric vehicle

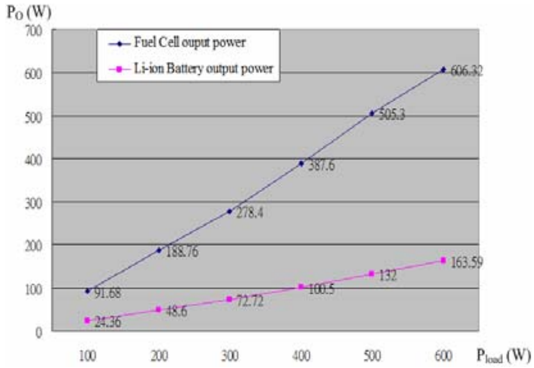


Figure 11: Fuel cell and Lithium-ion battery power output curve at normal state

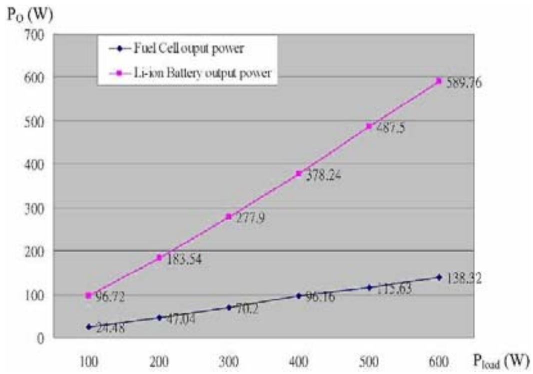


Figure 12: Fuel cell and Lithium-ion battery power output curve at hydrogen lack state

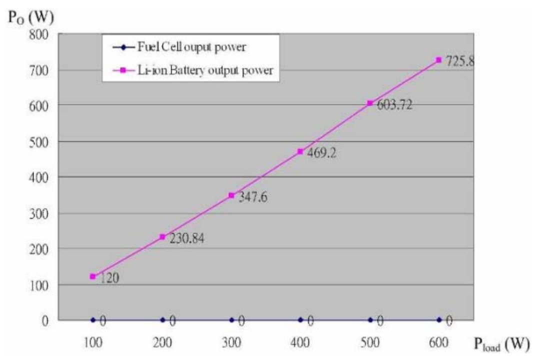


Figure 13: Fuel cell and Lithium-ion battery power output curve at fuel cell abnormality

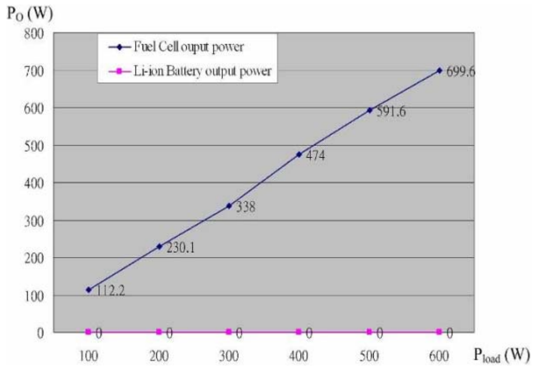


Figure 14: Fuel cell and Lithium-ion battery power output curve at Lithium-ion battery abnormality

6 Conclusion

Renewable energy is the new trend of the times. The green energy vehicles is used by the national attention in the environmental awareness and oil rising, which put forward a number of different electric vehicle architecture. The power converter is used to regulation devices for the fuel cell and lithium-ion battery output voltage in this article, and completing design of the power distribution control for hybrid power system load energy. The hydrogen storage bottle prevented freeze and increased travel mileage and safety for this hybrid electric vehicle architecture. Final, the micro-controller is used to read the fuel cell modules, the hybrid power distribution system and the working conditions displayed to show in LCD, which immediately can combine to use of state power.

References

[1] Sin-Wang Ye, Wen-Jin Li, "electric vehicles zinc - zinc-air battery anode recovery technology with the introduction", Industrial Materials 146, February 1999.

[2] C. C. Chan, "The past, present and future of electric vehicle development", in *Proc. IEEE Int. Conf. Power Electronics and Drive Systems*, 1999, vol. 1, pp. 11-13.

[3] W. Turner, M. Patten, D. Vines, J. Jones, and T. Maxwell, "Modeling a PEM fuel cell for use in a hybrid electric vehicle", 49th IEEE Vehicular Technology Conference, Vol. 2, 16-20 May, 1999, pp.1385 – 1388.

[4] K. Rajashekara, "Propulsion system strategies for fuel cell vehicle", Fuel Cell technology for Vehicles, PT-84, pp. 179-187, SAE publication, Warren dale, PA, 2001.

[5] P. Rodatz, G. Paganelli, A. Sciarretta and L. Guzzella, "Optimal power management of an experimental fuel cell/super capacitor-powered hybrid vehicle," *Control Engineering Practice* Vol. 13, Jan, 2005, pp 41-53.

[6] Ke Jin, Xinbo Ruan, Mengxiong Yang and Min Xu,"A Hybrid Fuel Cell Power System," *IEEE of Industrial Electronics*, April 2009.

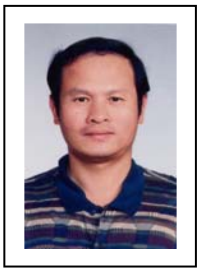
[7] J. Bauman and M. Kazerani ,"A Comparative Study of Fuel-Cell–Battery, Fuel-Cell–Ultracapacitor, and Fuel-Cell–Battery–Ultracapacitor Vehicles," *IEEE TRANS. ON VEHICULAR TECHNOLOGY*, vol. 57, NO. 2, MARCH 2008.

[8] P. Thounthong, S. Rael, B. Davat and I. Sadli,"A Control Strategy of Fuel Cell/Battery Hybrid Power Source for Electric Vehicle Applications," *37th IEEE of Power Electronics Specialists Conference*, June 2006, pp. 1 – 7.

[9] B.Fuchs, Lafond, O. Rondineau, S. and Himdi, M., "An Analytical Optimization Method for Improved Fuel Cell-Battery-Ultra capacitor Power train,"*Microwave Theory and Techniques, IEEE Transactions on*, vol. 54, June 2006, pp. 2292 – 2300.

[10] Ba-You Zen,"dsPIC digital signal controllers Principles and Applications-MPLAB C30 Development Practice", macro Friends of the Library Development Co., Ltd., in October 2006.

Author



Associate Professor: Van Tsai Liu
Department of Electrical Engineering, National Formosa University
Tel: +886-56315607
Fax: +886-56315609

He is currently an associate professor in the department of electrical engineering, National Formosa University, Yunlin, Taiwan. His research interests include intelligent control, high voltage gain converter, battery management system.