

Available online at www.sciencedirect.com**SciVerse ScienceDirect**

Procedia Environmental Sciences 10 (2011) 439 – 443

Procedia

Environmental Sciences

2011 3rd International Conference on Environmental
Science and Information Application Technology (ESIAT 2011)
Propulsion Control of Fuel Cell Electric Vehicle

Zhang Guirong , Li Houyu , Huang Fei

Shandong Jiaotong University, 250023 Jinan, China

Abstract

Fuel Cell Electric Vehicle overcomes the shortage of Battery Electric Vehicle, which uses only battery as its power source and has a short range. No warming-up process and free from carno cycle, Fuel Cell Electric Vehicle(FCEV) has a high energy convert efficiency and is friendly to environment. Internal Combustion Engine Vehicle does not have these advantages. At the same time FCEV still keeps the acceleration performance, high speed, long distance running, safety and comfort as traditional IC Engine Vehicle. Fuel cell is the power source of a Fuel Cell Electric Vehicle, it converts the chemistry energy into electric energy directly, and then the electric energy drive the electrical machine to make the vehicle move. FCEV's complete power train has four kinds of propulsion mode, they are fuel cell(FC) mode, fuel cell and battery mode(FC+B), fuel cell and capacitance(FC+C) mode and fuel cell and battery and capacitance(FC+B+C) mode. The fourth (F+B+C) can satisfy the start, acceleration, force and efficiency demand of braking of a vehicle to the maximum top, but the cost is the highest, the structure and control are the most complex. The general structure of the FCEV's complete power train system is the FC+B combination mode

© 2011 Published by Elsevier Ltd. Open access under [CC BY-NC-ND license](http://creativecommons.org/licenses/by-nc-nd/3.0/).

Selection and/or peer-review under responsibility of Conference ESIAT2011 Organization Committee.

Keywords: Fuel cell electric vehicle; Drive mode; Battery; Capacitance

1 Introduction

Along with the development and progress of society, traditional vehicles that take petrol and diesel as fuel continuously increases, lead the shortage of energy and pollution to a bad circulation. On one hand, vehicles use up a great deal of oil resource. On the other hand, the exhausts become the important pollution source of the world environment. Green house effect and acid rain all have important relation with the exhausts pollution. Energy and environment are the requirements of sustainable development.

The pressure of energy and environment pollution urge countries all over the world to look for new power device for city vehicles. Fuel cell is a device that can turn chemistry energy of hydrogen and oxygen into electric energy directly through electrodes' chemical reactions. The biggest characteristic is that the reaction process doesn't involve the combustion and heat lost for machine's movement, therefore the energy convert efficiency is free from the restriction of "carnot's cycle", up to 60%~70%,and the efficiency in actually use is about twice of the IC Engine. In addition, the only product of the reaction is water, which is clean and pollution-free. Because the little libration and disturb sound, simple structure and easy maintenance, and fuel no depend on oil resource, FCEV has been generally accepted as one of the best power source of automobile after IC Engine .

2 FCEV Technique Advantages

Fuel Cell Electric Vehicles (FCEV) use fuel cell as its power source, and convert the chemistry energy of fuel into electric energy directly, then the motor will run the vehicles. FCEV has the following technique advantages when compared with traditional vehicles, battery-powered vehicle and hybrid electric vehicle.

(1) Low Running Noise

1878-0296 © 2011 Published by Elsevier Ltd. Open access under [CC BY-NC-ND license](http://creativecommons.org/licenses/by-nc-nd/3.0/).

Selection and/or peer-review under responsibility of Conference ESIAT2011 Organization Committee.

doi:10.1016/j.proenv.2011.09.072

The fuel cell belongs to quiescent energy convert device. In addition to air compressor and cooling system there are no other running parts, therefore the running noise and vibration in the running process are lower compared with the IC Engine.

(2) Green and Environmental Protection

The Hydrogen Fuel Cell Electric Vehicle uses pure hydrogen as fuel, and its product is only water, with zero emission. The emission of other impure Hydrogen Fuel Cell Electric Vehicle is 1-2 times lower than that driven by petrol machine and diesel engine. Moreover, the emission of the CO₂ lowers 40%~60%. In the fuel cell the temperature is very low, the nitrogen oxidizing compound is not formed, the main composition of emission is water and the carbon dioxide, while system efficiency and chemistry process contribute to limiting carbon dioxide emission, and make it lower than homologous transportation vehicles' emission level. So generally speaking, using fuel cell as the power source of traffic tools is still advantageous to lower a greenhouse effect

(3) Strong Ability of Overload

Besides a higher working efficiency in a wider working rang, the short time overload capability of fuel cell can reach 200% of the rated-power or more.

(4) A Longer Rang

Adopting the fuel cell system as the energy source, when using the liquid carbon hydrogen fuel, Fuel Cell Electric Vehicle would have the equal rang as the IC Engine of the same size. When overcoming the disadvantage of short rang, the long distance driving ability of EV would approach to the traditional vehicle.

(5) Higher Energy Convert Efficiency

The energy convert route of internal combustion engine is the chemistry energy of fuel-heat energy-kinetic energy, but the operating process of fuel cell is the chemistry of the fuel energy-electric energy, its momentary overload ability may reach the rated power 200% or is bigger.

3 Basic Structure Type of FCEV

FCEV is substantially one kind of electric vehicle, in the body, power drive system and control system ...etc, FCEV and common electric vehicle are almost the same, the main difference lies in the operate principle of power battery.

Now the basic structure of FCEV of international manufactures has various forms. According to its energy source it can be divided into two kinds: on-board pure hydrogen FCEV and fuel reforming FCEV.

According to its driving pattern it can be divided into pure fuel cell driving and hybrid driving.

According to driving pattern FCEV can be mainly divided into four kinds of structure: single fuel cell(FC) system, fuel cell and assistant secondary cell unite driving(FC+B) system, fuel cell and super capacitance united driving(FC+C) system, fuel cell and battery and super capacitance united driving(FC+B+C) system. And the FC+B+C system is considered which will satisfy the start, acceleration, force and efficiency demand of braking of a vehicle to the maximum top, but the cost is the highest, the structure and control are the most complex. The general structure of the FCEV's complete power train system is the FC+B combination mode

According to the ratio of power provided by fuel cell in the complete power demand is different, the fuel cell hybrid electric vehicle can be divided into two types: energy mix type and power mix type.

In the earlier period of FCEV development, because of the restriction of technique level, the power of fuel cell is too small to satisfy the power demand of vehicle .In the driving, the fuel cell can only provide part of the complete power demand, the rest still need other power source to make up, this is the driving mode of energy mix type FCEV. For satisfying certain performance beacon, the energy mix type FCEV needs cells with big capacity, causing the deadweight increase, power performance becomes bad and decoration space tension. The fuel cell of energy mix type FCEV can keep working in high power efficiency region ,but each time after the running, we should add fuel and at the same time charge the battery with ground power supply.

Along with the development of fuel cell techniques, fuel cell performance is improved gradually, it provides bigger and bigger power ratio, so the capacity of battery reduces, then the vehicle weight reduces and power performance raises. But to recall the braking energy certain quantitative batteries are still needed. However they only provide a small part of the complete power demand. As fuel cell is the main force source and battery is assistant, the power of vehicle requirement

is mainly provided by fuel cell, the battery just does its part in fuel cell starting, climbing slope and accelerating, and recalling braking energy when braking. This is the driving mode of power mix type FCEV.

4 The Drive Control of FCEV

4.1 The Drive Control of FC

Below is the driving mode of FC driving system, seeing figure 1,



Figure 1 FC driving mode

The FC mode FCEV only has one power source—the fuel cell, all the power and load are undertaken by the fuel cell. Its structure is most simple, because the power of fuel cell needs to satisfy all requests of drive work conditions, its value will be very large, but it is very difficult to make high power fuel cell, so the FC mode FCEV is gradually decrease. But it also has some advantages: ① the control is simple, ② help to improve the overload capability.

For FC mode FCEV owns a few disadvantages: ①as fuel cell has a big power, it cost much and carload mass raise, the total energy and power expended increase. ②Though the fuel cell system has a high power, the number of hydrogen consumption will increase, and then mileage consumption of fuel arises, the cost increases.③The dynamic response and reliability of fuel cell system is hard to satisfy the demand of vehicle. ④The system can not recall the braking energy.

4.2 The Drive Control of FC+C

This kind of mix drive mode applies fuel cell as the main force source to provide sustainable power, the super capacitor as an assistant power source to provide the peak power, it is showed in figure 2.

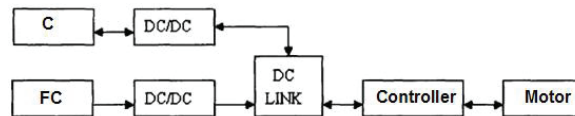


Figure 2 FC+C driving mode

The main advantages of FC+C mode are: ①The super capacitor has a burden balancing function, the discharge current decreases and then the use of battery energy and the circulation life will increase, while the cost gets lower. ②For the super capacitor can charge fast and discharge quickly it can be used to recall the regenerated energy of brake quickly and in high efficiency. FC+B mode has a simple structure, it solves the cold start and speeding climb problem of vehicle, and can develop the advantages of super capacitor. But the energy stores of super capacitor is limited, namely the specific energy is low, can only provide about 1 minute peak power.

4.3 The Drive Control of FC+B

Considering that currently fuel cell system itself has some specific requests, for example, power supply is needed while starting compressor or blower, the electricity pile needs to be heated, hydrogen and air need to be wet ...etc., meanwhile, for recalling the braking energy, battery and fuel cell system are united to make a mix power system. FC+B mode is a kind of popularly drive mode. Because of the battery the drive mode eases the pressure of fuel cell system, the requests for power density and cost of fuel cell are not as high as the FC mode .It is show in figure 3.

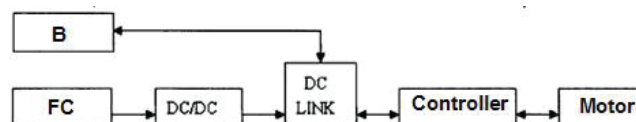


Figure 3 FC+B driving mode

Fuel cell is the main force source to provide sustainable power, and the function of battery is to recall the braking energy of vehicle, to provide energy supplement in the process of starting, climbing and accelerating. The main advantages of FC+B mode are: ①The power demand for fuel cell decreases. ②The fuel cell system starts easily. ③Once appear a fault, the battery can keep work, a higher system reliability. ④The braking energy can be recalled .

4.4 The Drive Control of FC+B+C

This mode parallels a set of super capacitors to the voltage electric mains, used for providing the peak current of (absorb) acceleration(urgent brake), and then lighten the burden of battery, lengthen its service life. The sustainable power are provided by fuel cell alone or together with battery, and in the start, climbing and acceleration ...etc. the battery and the super capacitors can provide this part of power alone or together, so the energy distribution becomes more reasonable. It is showed in figure 3.

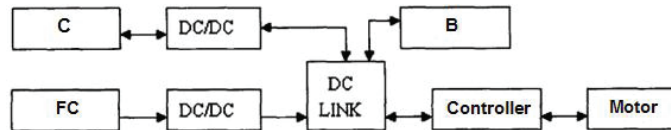


Figure 4 FC+B+C driving mode

There are three main advantages of FC+B+C mode: ①It can lower the power requirement to fuel cell and battery. ②When cold start the super capacitor provides enough starting power. Once the battery couldn't generate the current that big enough to start the vehicle, the battery will charge the super capacitor in small current, then the super capacitor will provide enough starting power. In this way, we can reduce the number of batteries and the capacity of each battery, and lighten the burden of the battery. ③When regeneration braking, the super capacitor store the energy of feed back, reduces the charge and discharge numbers of battery, increases the service life of the battery. But the structure of this mode is the most complex, the general control is also the most difficult, and its control strategy is more complicated.

Drive pattern of FCEV above, besides the single fuel cell (FC) mode, others all have two kinds or more energy store devices, energies or convertors as the drive power, and one of them provides electric energy at least.

5 Conclusion

Among drive modes of FCEV, the single fuel cell electric vehicle (FC) only has one power source—the fuel cell, all the power and load are undertaken by the fuel cell and the fuel cell has a big power, it costs much while the braking energy can not be recalled. In the FC+B mode, battery and fuel cell system are united to make a mix power system. It reduces the power and dynamic performance requirement of fuel cell, at the same time decreases the cost of fuel cell. The FC+C mode combines the fuel cell and super capacitor, makes use of the advantages of super capacitor, which has a long service life and high efficiency. In this way the cost reduces much, which is good for the commercial spread and application of FCEV. The FC+B+C mode parallels a set of super capacitors to the voltage electric mains, used for providing the peak current of (absorbing) acceleration (urgent brake), and then lightens the burden of battery and its service life.

References

- [1] Li Xinghu, Introduction of electric vehicles ,Beijing Institute of Technology Press , 2005.8
- [2] Zhu Ke, Study on Key Technology of the Power train System in Fuel Cell Bus, Hefei University of Technology,2007.3
- [3] Liu Fei, Selection and Simulation Research of Fuel Cell Electric Vehicle's Drive System, Wuhan University of Technology,2006.4
- [4] Cao Weiming, Research of Fuel cell / battery electric power system matching, Chongqing University,2004.5
- [5] Huang Naiyong, Modeling and Simulation of Driving System for a Fuel Cell Electric Vehicle, Wuhan University of Technology,2006.11
- [6] Wang Yong, Fuel cell electric vehicle power transmission system layout, modeling and simulation, Wuhan University of Technology,2004.2

- [7] Shin-ichiro Sakai and Yoichi Hori, Advantage of Electric Motor for Anti Skid Control of Electric Vehicle, EPE Journal, Vol. 11, No. 4, 2001.11
- [8] Xie Changjun, Research and realization of vehicles control and power flow management system of fuel cell electric vehicle, Wuhan University of Technology, 2004.4
- [9] Shin-ichiro Sakaia, Yoichi Hori, Advanced motion control of electric vehicle with fast minor feedback loops: basic experiments using the 4-wheel motored EV "UOT Electric March II, JSAE Review 22 (2001)