Applying Research On Fuel Cell Generation System

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Abstract. Fuel cell is attracted much attention as an efficient power, low-pollution means of generating electrical power. In this paper, the fuel cell power generation system problems are described in detail, and expounding on the principle of single battery, power system working principle, characteristics, and the simulation analysis made on the experience model of the fuel cell. The relevant theoretical reference is provided for the application of fuel cell.

Introduction

At present, with the rapid development research and application of fuel cells, getting a certain range achievements, widely used in power generation, automotive, submarines and aviation [1]. The new generation technology can reduce environmental pollution produced during conventional power generation. And the problem of geographical constraints and energy shortage of solar, which wind and hydro power generation technologies can not be solved. This combined system is widely used in remote areas or in harsh environments and other difficult cover geographical grid. However the fuel supply system is not established comprehensive, and the market price is too expensive. So it is an important factor restricting the development of the fuel cell.

Principle of The Unit Cell of The Fuel Cell

A fuel cell is an electrochemical device capable of converting chemical energy of two reagents directly into low voltage direct current electricity. The transformation is made by means of an electrochemical reaction, in which, the oxidant is usually air or oxygen. On the other hand, since the product is oxidized that is not part of the fuel cell structure and both products can be supplied uninterruptedly, the production of electricity will persist while there are reagents [2]. The basic operation of fuel cell is shown in Fig. 1. Comparing fuel cells with rechargeable batteries, in the later the chemical energy of the electrodes becomes electricity, when it is exhaust, it needs a recharge process. But in the fuel cells the chemical energy comes from a fuel that is supplied from outside, the operation method is the opposite of electrolysis. Fuel cells have a high electrical efficiency.

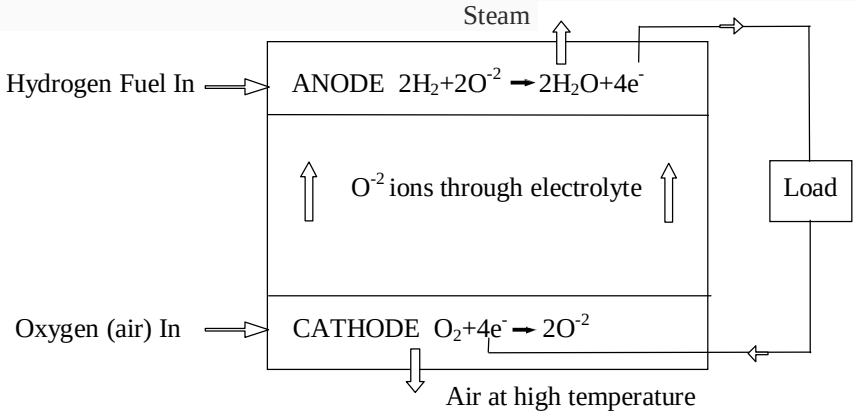

Fig.1. Fuel cell working principle

(1)

Relevant Characteristics of The Fuel Cell

Fuel cell can be divided based on two fundamental aspects: operating temperature and the electrolyte material. Regarding the temperature four models of low temperature (AFC, PEMFC, PAFC) and two of high temperature (MCFC and SOFC) are considered [3]. Some relevant aspects of these fuel cells are shown in Table1.

AFC. The cell voltage is in order of 0.8V. It works between 60-120˚C and uses pure hydrogen as fuel, with null concentration of CO or CO_2, to avoid notably reducing the efficiency. At present, because of the low-cost it can be widely applied in small fixed power generation device. Due to the limitations of alkaline fuel cell development, it is not as wide as the use of other types of fuel cells, and can not achieve significant commercial production.

PEMFC. Suitable for frequent occasion starter, with a quick start travel distance, long, simple structure, and low temperature work function that is the best choice of car power supply. They can be fed with reformed fuel and air. Every cell voltage is around 0.7V. PEMFC is a clean energy, and its 1.1MV hydrogen fuel cell generators can supply about 765 families, producing twice as much as the solar panels. PEMFC power system can be reduced by about 3.3 million pounds of carbon dioxide emissions, when using in the summer peak period.

PAFC. In addition to hydrogen, it can use inexpensive natural gas, coal gas. Compared with alkaline fuel cell, the most obvious advantages of PAFC is that without special equipment to deal with CO_2. Their response time is higher than PEMFC and they are used in fix installations with power ranges of 0.2-10MW. It is mainly used in the field of cogeneration systems.

MCFC. It is medium and high temperature fuel cells, it can operate with hydrogen, carbon monoxide, natural gas, propane and so on. Its efficiency is around 55%-57%, and when used in cogeneration, up to 85%.Compared with other technologies, this cell is capable of operating with a higher voltage than PAFC for the same current. When temperature falls around 30˚C, the voltage output is approximately reduced 15%.

SOFC. The electrolyte is a solid ceramic material that the temperature in range of 600-1000˚C. Their useful life is around 30000h. Burning material derived from natural gas, coal gas, methane, etc. This technology is very impressible, when the temperature reduces 10% causes 12% drop in energy efficiency. This is because of the resistance of oxygen conductivity.

Table1. Fuel cell relevant characteristics

Technology	MCFC	PEMFC	SOFC	AFC	PAFC
Fuel	H_2,CO,CH_4	Pure H_2	H_2,CO,CH_4	Purest H_2	H_2,CH_3OH
Temperature(˚C)	600-700	60-80	750-1050	60-250	130-220
Catalyst	Ni	Pt	Perovskites	Pt,Ni	Pt
Electrical efficiency	55-57%	30-50%	50-60%	32-70%	40-55%
Electrical with cogeneration	85%	70-85%	85%	70%	85%
Power density (mW/Cm^2)	100-300	300-1000	250-350	150- 400	150-300
Poisons	S,H_2S,HCl HI	CO,H_2S	H_2S	CO_2 H_2SCO	CO,H_2S
Power range	500KW-10MW	1-1000 KW	1KW-10MV	1-100 KW	200KW-10MW
Application	Transport stationary	Space portable transport stationary	Transport stationary	Space portable transport	Transport stationary

Fuel Cell Power Generation System Features

The fuel cell power generation system can provide additional forms of electricity generation while others can not, such as: the diversity of fuel, high reliability, high conversion efficiency, waste heat reusability, cold start, high temperature working, low pollution, low noise and a nearby installation. 1) Diversity of fuel. The fuel cell is fed with natural gas, methanol, ethanol, gasoline, coal, waste wood, and waste paper, also use the city's waste and microorganisms present in seawater quality. 2) High reliability. By adjusting the output of the power and voltage, to meet customer needs. The modular structure of the fuel cell stack is small rotating member, making it easy to assemble and repair. Almost does not occur any accident when use this system. Never appear malignant fault, such as rotating parts failure thus the system more secure and reliable. 3) High conversion efficiency, and waste heat reusability, current conversion efficiency of the fuel cell is 43% -58%, and when used in cogeneration, up to 85%. In order to minimize transportation cost and transport loss, fuel cell power plants can be installed in user surrounding nearby. 4) Start in low temperature, high temperature work. The new PEMFC work at 180 ˚C -200 ˚C, do not need external humidifiers and other auxiliary equipment, therefore, the fuel cell is greatly reduced cost and size. 5) Low pollution, low noise. Hydrogen fuel cells generate only water after reaction, so the most obvious feature is not substantially generated NO_x, SO_2 and other toxic gases compared with other production electric mode. The comparison of air pollutant emissions from the major power generation technology is shown in Table 2.

Table2. Comparison of air pollutant emissions from the major power generation technology

Pollutants	Fuel thermal power	Natural gas thermal power	Coal thermal power	Fuel cell power generation
Hydrocarbon	135-5000	20-1270	30-104	4-102
Dust	45-320	0-90	365-680	0-0.14
NO_X	3200	1800	3200	63-107
SO_2	4550	2.5-230	8200	0-0.12

The Working Principle and Structure of the Fuel Cell Power Generation System

The fuel cell power generation system has a low voltage and high current output characteristics, as shown in Fig.2. The fuel cell power generation system consists of an active clamping dc/dc converter, fuel cell module, a conventional full-bridge DC/AC inverter, LC filter and load. According to the producing principle of fuel cell, the fuel cell output is Low voltage direct current, dc/dc converter receives the fuel cell output voltage, and supplied to the inverter input voltage and stable operation [4]. The fuel cell can not accept rapid load change, so in its DC side shunt connection a battery pack. An LC filter to filter out high frequency voltage, and load output for an ac 220 v/60Hz voltage [5].

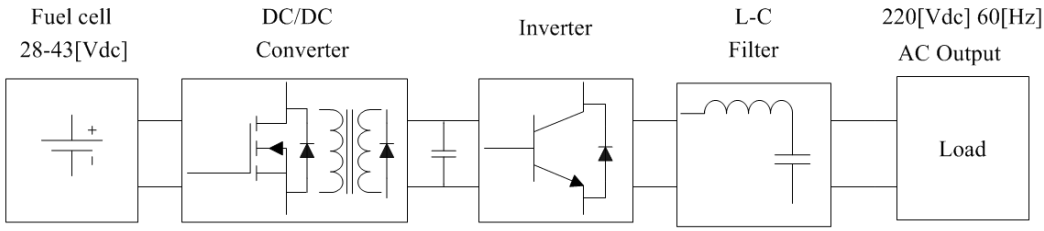

Fig.2 Fuel cell power generation system structure

Simulation and Experimental Results

The proposed system is simulated with Simulink software. It is observed in Fig.3 that the empirical model is became a good response relationship of the fuel cell current density and battery voltage. The relation between the output voltage and current density of fuel cell as follows:

$$V = E_{oc} - ir - A\ln(i) + m\exp(ni) \quad (1)$$

Where E is reversible open circuit voltage, A is Tafel slope, where m and n are fixed constant, and r is the battery internal resistance.

$$E_{OC} = E + A\ln(i_0) \quad (2)$$

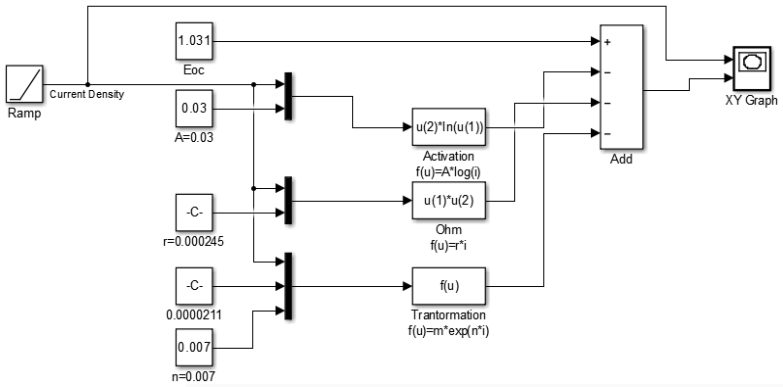

Fig.3 Empirical model of Fuel cell in Matlab/Simulink

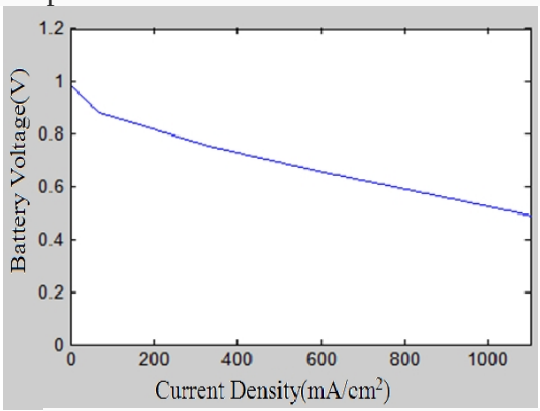

Fig.4 The fuel cell polarization curve VI

The simulation voltage and current waveforms of fuel cell is shown in Fig.4. Fully reflects the activation polarization has influence on the starting voltage, effects on the cell voltage by concentration polarization in the region of the high voltage density. In the low current density region, activation polarization larger influence on the output voltage of PEMFC, voltage rapid decline, then the output voltage of PEMFC with increasing current density is decreased.

Conclusions

This article presents a view of fuel cell generation system as renewable to produce a superior overall efficiency, compared with their separated operation. 1) The paper presents the most outstanding characteristics of the following fuel cells technologies: AFC, PEMFC, MCFC, SOFC and PAFC. 2) A brief overview of the principle of the fuel cell power generation system is given. 3) The empirical model of the fuel cell power generation system is simulated and analyzed, the theoretical basis is provided for application of fuel cells.

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