RESEARCH ON SOFC GENERATOR MODEL BASED ON GAS DETECTOR

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ABSTRACT: Fuel cell power generation system is one of the friendly, non-polluting and efficient power generation technologies. It has the advantage of zero pollution and extensive application prospects. Compared with other fuel cells, solid oxide fuel cell (SOFC) has high conversion efficiency and long use cycle, thereby raising people's attention. At the same time, the solid oxide fuel cell has high sensitivity and it can detect a variety of gases. SOFC has a long service life, and it has great potential in gas detection applications. In this paper, we study the solid oxide fuel cell generator system. The system can release the inductor energy on the converter and reduce the charge time. In the meantime, we add a flyback winding transformer to the DC/DC converter. In the aspect of inverter, we use the fuzzy PID control strategy. Therefore, when the output voltage of the solid oxide fuel cell is unstable, the corresponding control output will be adjusted by monitoring system.

KEY WORDS: SOFC, gas monitor, generator.

1 INTRODUCTION

A fuel cell is a power generation device. The chemical energy and oxidant stored in the fuel can be efficiently converted into electrical energy. The fuel cell consists of anode, cathode and electrolyte. The fuel is oxidized at the anode and the oxidant is reduced at the cathode, thereby completing the entire chemical reaction (Adler, Stuart B., 2014). The fuel cells are classified into the following five types according to the type of electrolyte: alkaline fuel cells, phosphoric acid fuel cells, polymer electrolyte fuel cells, molten carbonate fuel cells and solid oxide fuel cells. This paper uses the solid oxide fuel cell (SOFC).

In a solid oxide fuel cell, its electrolyte is solid oxide. This kind of fuel cell power generation technology is an advanced and clean power generation technology. Its power generation mechanism is different from traditional power generation. At the same time, its power generation efficiency is not limited by the efficiency of the Carnot cycle, and it is highly efficient power generation equipment. The fuel cells are often used as the power generation device for the building cogeneration systems. It integrates the efficient energy conversion manner and usage mode.

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Solid oxide fuel cell is of great significance to improve energy efficiency and environmental quality (Haseli, Y., et al.,2008; Hibino, Takashi, et al.,2000; Laguna-Bercero, M. A. ,2012; Leonide, André, et al.,2008; Ormerod, R. Mark.,2003).

Solid oxide fuel cell currently has two basic applications, one is the fuel cell power generation system research and design, the other is the gas sensor design. Solid oxide fuel cell is a new type of fuel cell, and it can solve the problem of electrolyte leakage. In the high temperature reaction, it can solve the problem of CO gas poisoning. Therefore, in the field of clean and efficient distributed power generation, it has great research value.

2 BASIC WORKING PRINCIPLE OF SOFC

The working steps of the SOFC mainly consist of four parts: (1) inputting the reactants to the fuel cell; (2) electrochemical reaction; (3) ion conduction through the electrolyte, electrons conducting through the external circuit; (4) outputting the product from the fuel cell discharge. The specific work steps are as follows.

Step 1: Reactor transmission. Due to the power generation function of the fuel cell, we need to continuously provide fuel and oxide. Therefore, we have to consider the performance influence of fuel cell shape, size and mode. In the meantime, the problem of electrode materials is equally important. The characteristics of the material are very restrictive to the material composition, including electrical, thermal, mechanical properties and corrugated requirements (Sarantaridis, D., 2007; Shaigan, Nima, et al., 2010).

Step 2: Electrochemical reaction. Once the reactants are delivered to the electrodes, they will undergo an electrochemical reaction. The size of the current generated by the fuel cell is directly related to the speed of electrochemical reaction. When the electrochemical reaction becomes faster, the current generated by the fuel cell becomes larger. Dull electrochemical reactions result in lower current output. Catalysts are often used to increase the speed and efficiency of electrochemical reactions.

Step 3: Ion and electron conduction. The electrochemical reaction that occurs in the second step will produce or consume ions and electrons. The ions generated by the electrodes will be consumed on the other side of the electrode. In the meantime, the electrons generated by the electrodes on one side will be consumed on the other side of the electrode. In order to maintain charge balance, these ions or electrons must be transferred from the regions they produce to the areas where they are consumed. For electrons, this transmission is quite easy. When the conductive path is present, the electrons will flow from one electrode to the other. Thus, a wire between the two electrodes provides a path to the electrons (Shim, JoonHyung, et al., 2007; Wachsman E D et al.,2011; Wilson, James R., et al.,2009;Yokokawa, Harumi et al.,2008).

However, the transmission of ions is relatively difficult, mainly because the ions are larger and heavier than electrons. Moreover, the electrolyte can provide a path for the flow of ions. In many electrolytes, ions move through the "jump" mechanism. This process is very inefficient compared to electron transport. Therefore, ion transport may exhibit significant resistance losses, thereby reducing the performance of the fuel cell. In order to weaken this effect, the electrolyte in the fuel cell should be as thin as possible, so as to shorten the ion transport path.

Step 4: The discharge of the product. In addition to electricity, the reaction of all fuel cells produces at least one product. For example, oxygen fuel cells generate water, and hydrocarbon fuel cells generate water and carbon oxides (CO2). If these products are not discharged from the fuel cell, they will accumulate over time in the battery. This will prevent the new fuel and oxide reaction, and ultimately make the battery "suffocated" to die. Fortunately, the action of transporting reactants into the fuel cell will often also contribute to the discharge of the product from the fuel cell.

3 SYSTEM MODEL DESIGN

SOFC generator system model is shown in Figure 1. It consists of solid oxide fuel cell module, isolated full-bridge boost converter, single-phase full-bridge inverter, filter composition. Fuel cell stack output low voltage direct current. The pre-stage inverter section uses an isolated full-bridge boost converter circuit to increase the DC bus voltage for the supply of the post-stage inverter. When the post-stage inverter receives a stable high-voltage direct current, the high-order harmonic interference will be filtered out by the filter.

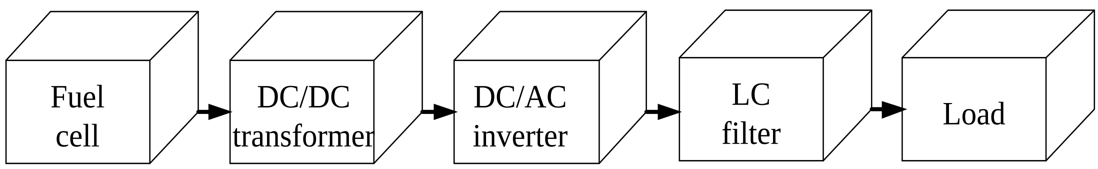

Fig.1 System structure diagram of solid oxide fuel cell generator

3.1 DC/DC transformer

When the load power of the solid oxide fuel cell is changing, the voltage fluctuation range is between 28~43 V. The purpose of the isolated boost full bridge converter is to raise the low voltage of the fuel cell stack to meet the DC /AC inverter of the direct current bus voltage. Conventional single-stage inverter structure cannot meet the requirements of solid oxide fuel cell inverter. Solid oxide fuel cells require two-stage inverters, because the solid oxide fuel cell itself is the thermoelectric combination system, the fuel cell voltage is unstable. The design of the preamplifier structure must conform to a wide range of voltage, current, current limiting and fast response times.

In this paper, we add a flyback windings transformer to the input inductor based on the isolated circuit of the boost converter. The purpose is to release the energy that the inductor cannot release through it. Therefore, the life of the equipment will be extended. At the same time, the device starting time is fast and the charging time is short, in order to achieve rapid boost function. The output DC voltage deviation signal is processed by PI link, and then modulated by PWM. Therefore, the duty cycle control power switch operation will be obtained. The voltage feedback uses the traditional PI lag compensation control

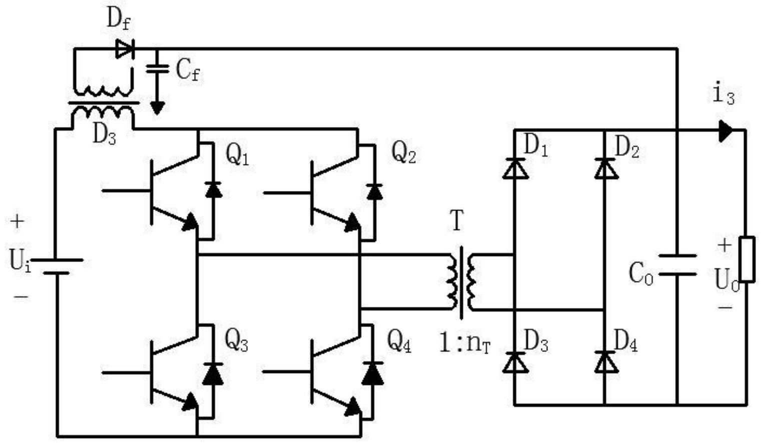

Fig.2 Improved DC/DC converter

Figure 2 is an improved full bridge boost converter. Soft start program: when the duty ratio is $0 < D < 0.5$, DC/DC converter is Buck work mode. In this case, the flyback winding transformer will work. In the ON stage, Q1, Q4 or Q2, Q3 will be conducted, and the energy will transferred to the load through the transformer. In the OFF stage, Q1, Q2, Q3, Q4 are off, the inductor failed to release the energy through the flyback winding transformer.

3.2 DC/AC inverter

The post-stage inverter uses a single-phase full-bridge inverter. It converts the high-voltage into an alternating current, so as to satisfy the normal use of the load. In this paper, we increase the circuit between the two levels of conversion between the additional filter circuit, so as to reduce the power load capacity requirements, and improve power generation efficiency

The output voltage of solid oxide fuel cell is influenced by temperature, pressure and flow. Therefore, in the aspects of single-phase full-bridge inverter, we use fuzzy PID control technology to improve the stability of solid oxide fuel cell power generation system. The open-loop transfer function Ti is the integral time constant, and the Kp, Kd, Ti. The fuzzy PID control technique can output a voltage and a given voltage difference by monitoring the solid oxide fuel cell system. At the same time, it can adjust Kp, Kd, Ti, and then get the output control.

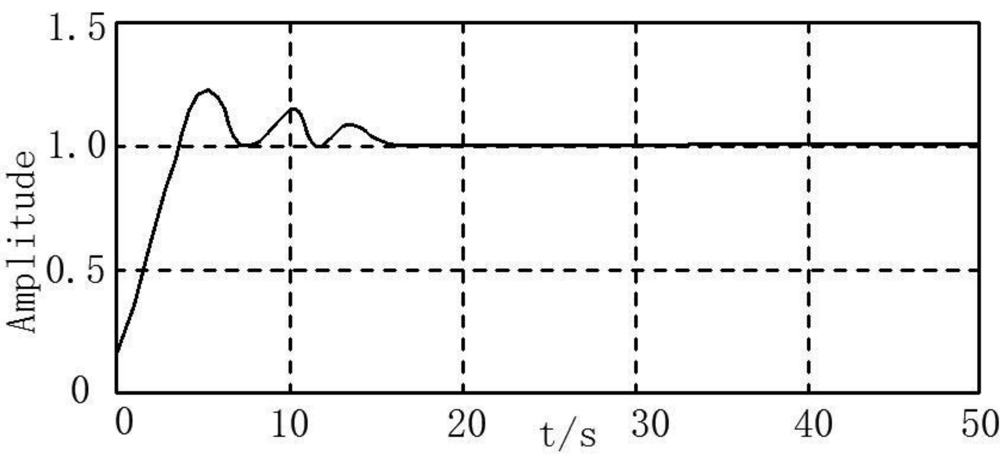

Fig.3 Traditional PID control chart

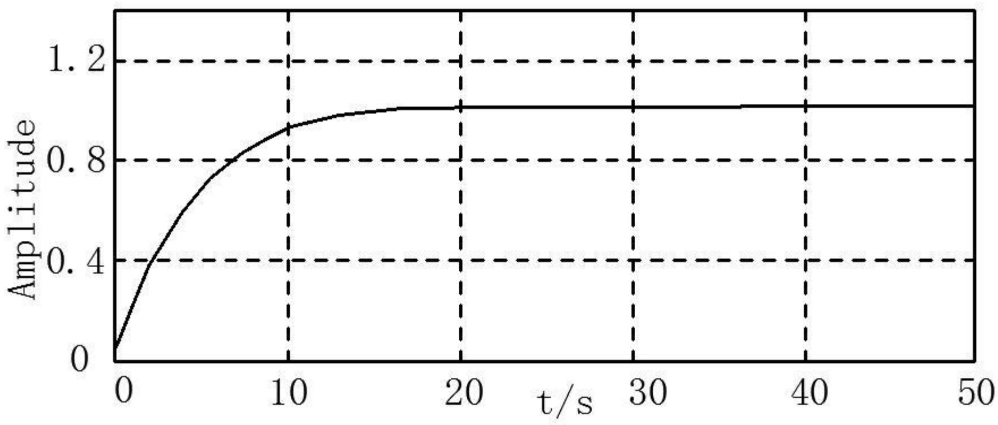

Fig.4 Fuzzy PID control chart

Figure 3 is the traditional PID control technology step response diagram, and figure 4 is the fuzzy PID control technology step simulation. It can be seen from Figure 3, between 0 ~ 15 s, the curve rose steadily. After 16s, the system reaches a steady state. Compared with the traditional PID control technology, fuzzy PID control technology overshoot is small, and the control process did not produce shock. The technology has fast response speed and good robustness.

4 SIMULATION RESULTS ANALYSIS

According to the above design method, we build a solid-oxide fuel cell generator system based on Matlab software. Figure 5 is a simulation of the DC bus voltage of the Boost converter. Figure 6 is a simulation of the DC bus voltage of an isolated boost converter. Figure 6 is SOFC power system step-up process of boost converter, which is 0~1.5s. The voltage rises rapidly from zero to 0.5 W, and then the voltage returns to the ideal state rapidly, and reaches the steady value after 0.83 s. It can provide a stable DC bus voltage to the inverter and output smooth voltage waveform. Compared to the Boost converter, the boost vibration is small and the charging time is fast.

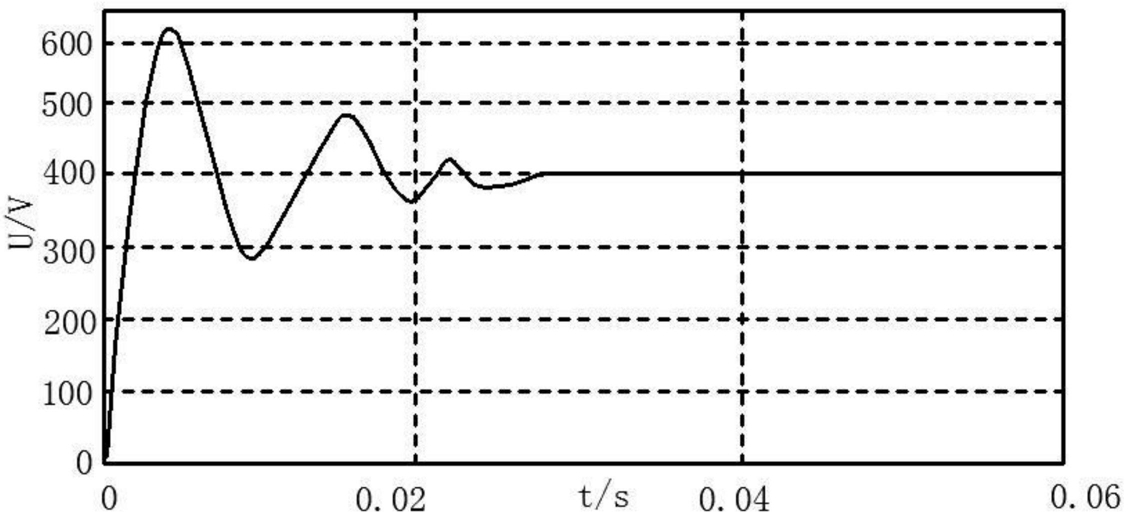

Fig.5 DC bus voltage of the Boost converter circuit

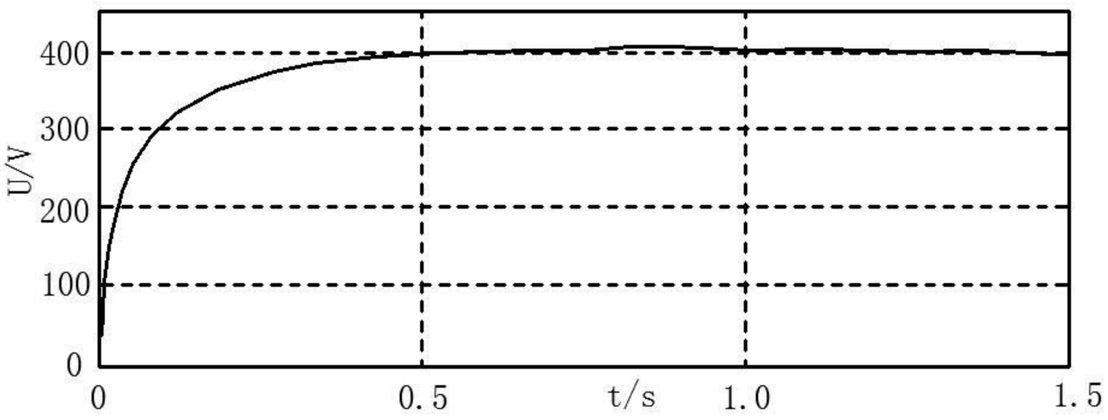

Fig.6 DC bus voltage of isolated full-bridge inverter circuit

Figure 7 is the output voltage diagram of full-bridge inverter circuit. Single-phase full-bridge inverter will invert the high-voltage DC into sinusoidal alternating current. When the load is mutated, the DC / AC inverter can operate normally. The output sinusoidal voltage (220V / 50Hz) waveform is stable. When the load is mutated, the DC / AC inverter can operate normally. Therefore, the above SOFC generator system design meets the requirements.

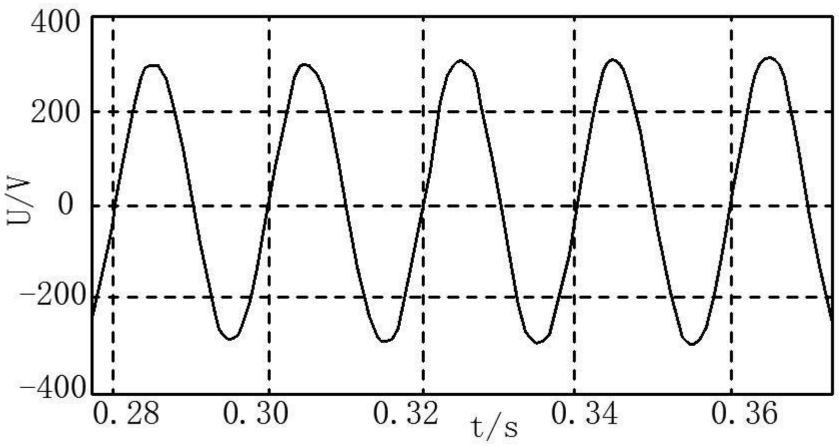

Fig.7 The output voltage diagram of full-bridge inverter circuit

In this design, we use the improved full-bridge converter as DC/DC converter. It can solve the problem of voltage oscillation in the process of boosting, and can provide fast charging method. At the same time, the rated output voltage curve is smooth. Therefore, when the stable AC is supplied, it can ensure the DC/AC inverter can work properly. Compared with the traditional PID control, the fuzzy PID control strategy is more suitable for the object with large parameter change. So the DC / AC inverter adopts fuzzy PID control method to guarantee the stability of the electricity consumption of the SOFC system.

5 CONCLUSION

Fuel cell power generation system is one of the friendly, non-polluting and efficient power generation technologies. It has the characteristic of zero pollution, and it also has extensive application prospects. In the meantime, SOFC cell has high conversion efficiency and long use cycle, thus raising people’s attention. Moreover, the SOFC has high sensitivity and it can detect a variety of gases. SOFC has a long service life, and it has great potential in gas detection applications

In this paper, we study the solid oxide fuel cell generator system. The system can release the inductor energy on the converter and reduce the charge time. In the meantime, we add a flyback winding transformer to the DC / DC converter. We use the fuzzy PID control as inverter. It can improve the stability of the output voltage, reduce the overshoot, and verify the design requirements. In the meantime, when the output voltage of the solid oxide fuel cell is unstable, the monitoring the system will provide the difference value between the output voltage and given voltage. In this way, the corresponding control output will be adjusted. In the power generation process, if the mutation occurred in SOFC, the system can still run stably. Through the system simulation, we can see that the system control strategy is good.

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