A Pulse-width Modulation Based DC-DC Converter for Electric Propulsion

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Abstract

A DC-DC converter is designed according to the request of the electric propulsion system for a fuel cell sightseeing car. The converter adopts a simple topography - full bridge circuit. The main switch transistors are driven by the module TL494, based on pulse-width modulation method. A high accuracy linear optical coupler is used to isolate analogy signal in order to guarantee the stabilization of the converter. Experiments show that the converter can satisfy the requirements of the power match between the fuel cell and the motor under the ordinary operation conditions.

Keywords

converter, electric propulsion system, full bridge circuit, pulse-width modulation

1. INTRODUCTION

Because of the expensive price, fuel cell is not adopted as the power supply for personal electric vehicles nowadays. [Parten, 2001; Anderson and Anderson, 2004; Chen et al., 2002] The fuel cell has obtained some applications in the low power electric vehicles, such as golf vehicles, sightseeing cars and so on. This article aims to design a matching DC-DC converter for a 5.0KW fuel cell sightseeing car and to accomplish correlative experiments.

The sightseeing car drive system has a wide velocity modulation range and the requirement of acceleration and deceleration frequently during the driving process. Because of the limitation of fuel cell performance index, if the drive motor adopts the cell directly, the drive performance will become worse. As a result, in order to guarantee the required DC power, the DC-DC transformation should be established in the electric vehicle propulsion system. The DC-DC converter performance affects the propulsion characteristics of the entire vehicle directly.

According to the specification of the car, a 5.0KW DC-DC converter is designed. The correlated experiments indicate that, the converter has high quality output voltage, is easy to control, and can well realize the power match between of the fuel cell and the DC motor.

2. DC-DC CONVERTER

The main circuit of the converter uses the full bridge transfer circuit and adopts voltage-current loops control. [Xia and Guo, 2006; Zhang and Yin, 2003; Dong, 2000] The range of input voltage in the converter Vin is 100-150VDC, input current Iin is 0-50 A. Output voltage Vout is 0-48VDC, output current Iout is 0-100A. Working temperature range is -10-+55ºC. Working humidity is 5-95 %. Cooling way is forced-air radiation. Figure1 shows the overall construction of the DC-DC converter. The converter is divided into four modules, including the main power transforms circuit module (including transformer), the control module, the drive and protection module, and the isolation module.

Adopting the modules, the power transform system has the characteristics of short design cycle, high reliability, promoting system easily and so on. Along with the application of semiconductor process, package technique and high frequency soft switch method, the density and efficiency of the converter become higher and higher, the application is simpler and simpler.

The main circuit of the converter uses the full bridge transfer circuit. The interior adopts the redundancy design, so the transformer isolation security and the reliability are better. Using double close loop control of the current and voltage, the converter has the ability of

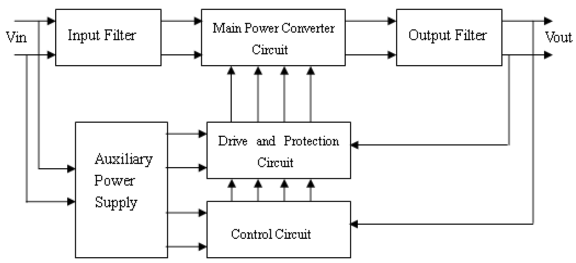

Fig. 1 Principle scheme of DC-DC converter

over-current protection and the temperature protection. The DC-DC converter can completes the voltage transformation from unstable DC voltage to stable. With the PWM technology, the differential voltage of the linear voltage-stabilizer circuit both sides is reduced, and the power in the circuit consume drops heavily.

The silicone material is used to seal because of its good insulating ability, high mechanical strength and good heat conduction. But the power modules have high temperatures, so when adopting the surface pastes technology, the more attention should be paid to the heat matching between paste component and the foundation plate.

2.1 Main circuit

The main circuit uses H bridge topography which is consist of four IGBT transistors. Output circuit using bridge rectifier has the advantage of the diode which only can bear AC voltage amplitude in the off-state, moreover the structure of transformer winding is simple. During the work, the average current flowing through each diode is half of the average current flowing through the inductance L. The structure of the main circuit is shown as Figure 2.

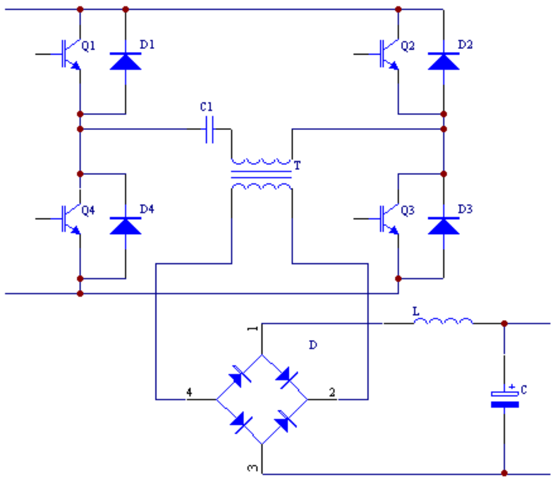

Fig. 2 The main circuit of DC-DC converter

2.2 Control circuit

The control circuit is the core of the converter, which decides the dynamic stability of the converter. This DC-DC converter realizes the single loop controller with TL494. The controller consists of TL494 which is the core component, the simple filter circuit and the RC electric discharge loop. In order to realize the single close loop control, the controller transforms the signal changes of pulse width into the direct-current signal which is proportional to the pulse width. The control circuit schematic diagram of the converter is shown as Figure 3.

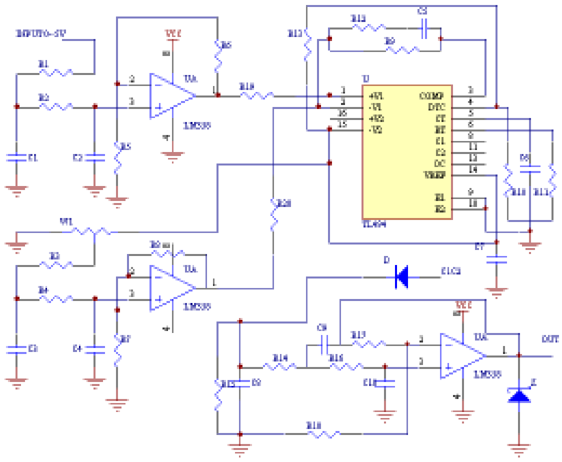

Fig. 3 The control circuit of DC-DC converter

3. EXPERIMENTS

Experiments mainly test the fire waveforms of IGBT, transformer output voltage, and output DC voltage of the converter. Test system components and test environment are shown as Figure 4. The IGBT driver test wave, transformer output voltage waveform, and output DC voltage waveform of the converter are respectively shown in Figure 5, Figure 6, and Figure 7.

4. CONCLUSION

The circuits in Figure 2 and Figure 3 are used in the DC-DC converter of the 5.0KW fuel cell sightseeing car. The converter has the simple structure in hardware and

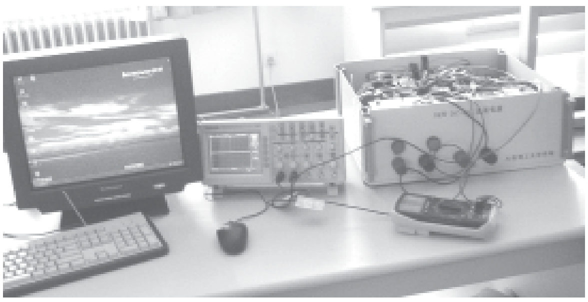

Fig. 4 DC-DC converter in test

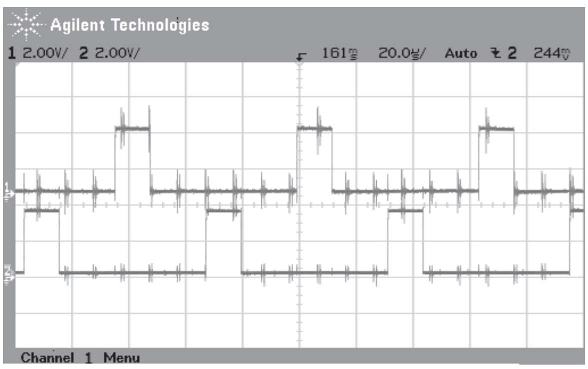

Fig. 5 IGBT driver waves

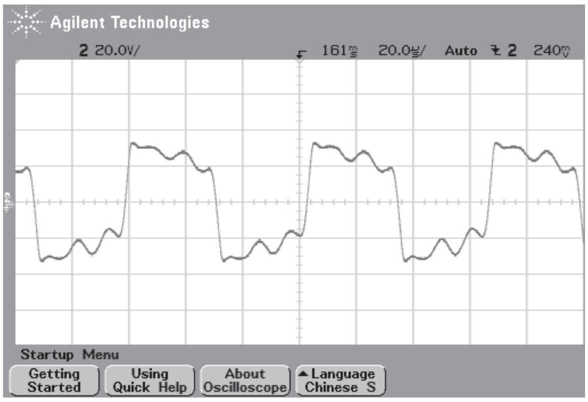

Fig. 6 Output wave of transformer

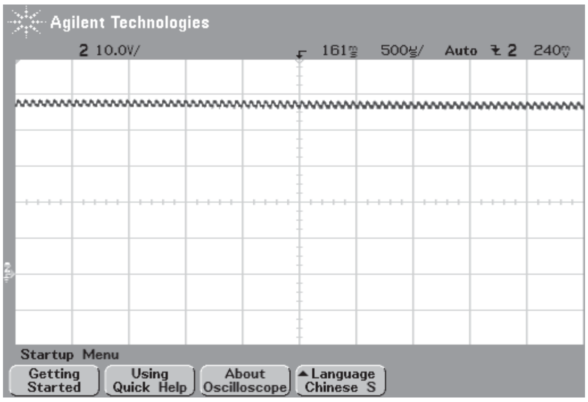

Fig. 7 Output wave of the converter

lower power losses, and is easy to realize and strong to resist disturbance. The experiment results in Figure 5, Figure 6, and Figure 7 shown that, the converter can satisfy the requirements of the fuel cell system and DC motor in common conditions.

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