Research on Energy Feedback Device

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Abstract: The hardware of this system is mainly composed of full-bridge DC/AC-AC/DC circuit system and DSP control circuit system, including DSP control system, AD sampling circuit, single-phase full-bridge circuit, transformer circuit and filter circuit. The DSP outputs eight PWM signals to control the on/off of the inverter MOS tube. The output is fed back by the current-voltage transformer, sampled by the A/D converter, and transmitted to the DSP control circuit to adjust the output to form a closed-loop control. Among them, the inverter link adopts single-phase full-bridge inverter circuit, SPWM control method with single-pole frequency multiplication, segmented synchronous modulation voltage frequency; constructs coordinate system through virtual orthogonal vector, and real-time voltage on inverter output side control. The energy feedback link uses a feedforward direct current controlled single-phase full-bridge PWM rectifier to improve energy feedback efficiency by adjusting the power factor. Finally, the software and hardware systems are jointly debugged, and the hardware and software have achieved the intended purpose.

Keywords: *SPWM, Synchronous Modulation, Virtual Quadrature Vector, PWM Rectification, DSP*

I. INTRODUCTION

In the variable frequency speed control transmission system consisting of general-purpose inverter, asynchronous motor and mechanical load, when the position of the motor can be driven down, the motor may be in the regenerative braking state, and when the motor is from high speed to low speed (including When the vehicle is decelerating, the frequency can be suddenly reduced. However, due to the mechanical inertia of the motor, the motor may be in a regenerative power generation state. The energy feedback device returns the regenerative electric energy to the AC power grid for use by other nearby electrical equipment, thereby saving energy. Both German and Japanese companies have developed a four-quadrant inverter or power regeneration unit that feeds regenerative energy back into the grid. However, the common problem with these devices is that these devices are expensive, and some products have high requirements on the power grid, which is not suitable for China's national conditions. In China, most of the medium and small capacity systems use the energy consumption braking method, that is, the electric energy is consumed in the high-power resistor by the built-in or external braking resistor to realize the four-quadrant operation of the motor. Although the method is simple, the disadvantage is obviously, wasting energy and reducing the efficiency of the system, the resistance heat is serious, affecting other parts of the system to work normally, simple energy consumption braking sometimes can not suppress the pumping voltage generated by rapid braking in time, limiting the improvement of braking performance. The energy feedback device adopts the SPWM control method of single-phase full-bridge single-pole frequency multiplication, and the energy feedback efficiency can be effectively improved by adjusting the power factor.

II. DESCRIPTION OF THE PROGRAM

The overall system plan framework is shown in Fig. 1. The single-phase full-bridge inverter circuit converts direct current into alternating current, and its output is LC filtered and sampled, and connected to a single-phase full-bridge rectifier circuit. The output voltage of the inverter is controlled in real time by using PI adjustment based on virtual orthogonality vector. The rectifier converts the alternating current into direct current and feeds it back to the input, which together with the direct current power supply powers the inverter, thereby achieving energy saving.

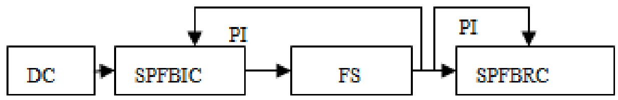

Fig. 1 Overall system plan framework

Label:
SPFBIC----Single-phase full-bridge inverter circui
FS----Filtering and sampling
SPFBRC----Single-phase full-bridge Rectification circuit

III THEORETICAL ANALYSIS AND CALCULATION

A. Inverter control and modulation strategy

The output voltage of the inverter is controlled in real time by PI adjustment based on virtual orthogonal vector. Output current in a single-phase system u_α ,delay 90° virtual one orthogonal component u_β , the synthesis constitutes a virtual vector in a two-phase stationary coordinate system U_o .Transform u_α 、 u_β by the Park, you can get the corresponding virtual vector.*d* Shaft and shaft DC components. Let the output side voltage of the single-phase inverter u_α for:

$$u_\alpha = U\cos(\omega t + \varphi)$$

u_α will shift the term 90° to get a virtual orthogonal variable u_β ,which is:

$$u_\beta = U\sin(\omega t + \varphi)$$

The DC components of the d-axis and q-axis are:

$$\begin{pmatrix} U_q \\ U_d \end{pmatrix} = T(\theta)\begin{pmatrix} U_\beta \\ U_\alpha \end{pmatrix} = \mathrm{U}\begin{pmatrix} \sin\varphi \\ \cos\varphi \end{pmatrix}$$

B. Rectifier control and rectification strategy

Single-phase PWM rectifiers have two main control targets. One is to output a stable DC bus current; the other is to obtain a unit input power factor. Feedforward direct current control is a double closed loop control strategy for DC current outer loop and AC current inner loop. The outer ring performs PI control on the DC side output current to obtain a stable DC bus current output. The output of the DC current outer loop PI controller is used as the amplitude given by the input current. The AC current inner loop, through the action of the current loop controller C, enables the actual value of the AC input current to quickly and accurately track the given value.

IV. CIRCUIT AND PROGRAM DESIGN

A. Overall system circuit

The overall system circuit is shown in Fig.2.

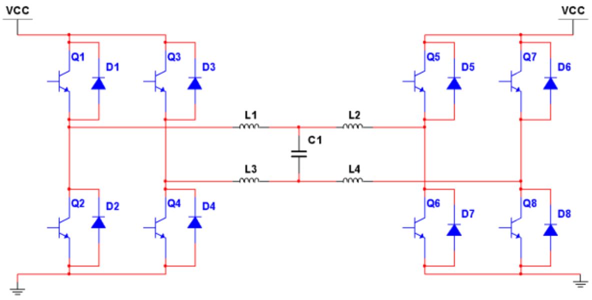

Fig. 2 overall system circuit

B. Single-phase full bridge module

The circuit design uses MOSFET single-phase full-bridge inverter and rectifier circuit. The DSP controller generates a driving circuit built by the SPWM to the TLP352 chip, and the driving circuit controls the on and off of the MOS transistor. The inverter output pulse waveform is LC filtered to become a stable sine wave, which enters the rectification section to generate DC power. Single-phase full-bridge inverter and rectifier module are shown in Fig. 3.

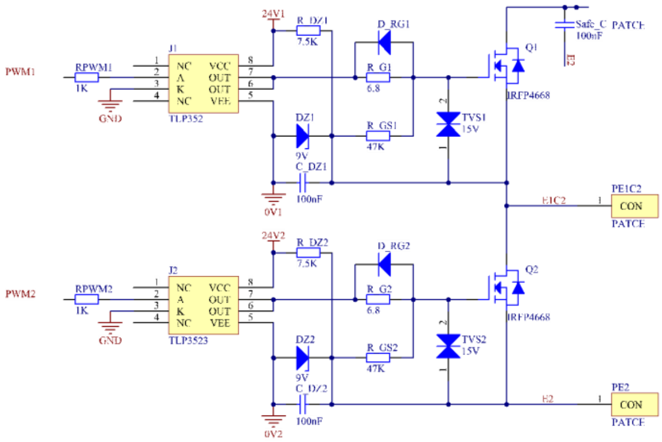

Fig. 3 Single-phase full-bridge inverter and rectifier module

C. Control program flow chart

The flow chart of the inverter program is shown in Fig. 4.

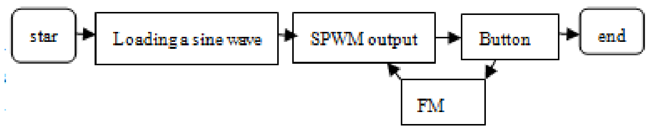

Fig. 4 Inverter Program Flow

The flow chart of the energy feedback program is shown in Figure 5.

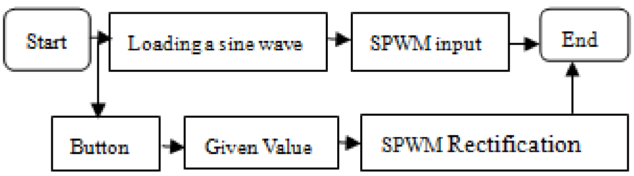

Fig. 5 rectifier program flow chart

V. TEST PLAN AND TEST RESULTS

A. Frequency conversion regulator

Test program

Step 1: Connect the two ends of the inverter to the resistor and connect the probe of the oscilloscope to both ends of the load.

Step 2: Adjust the frequency to 50Hz, observe the voltage amplitude across the load with an oscilloscope, and measure the current value on both sides of the load with a current clamp.

Step 3: Press the FM button to change the frequency of the DSP output SPWM, observe the voltage frequency change and voltage amplitude with an oscilloscope and measure the load current with the current clamp.

The results of the voltage regulation test are shown in Table 1, and the results of the frequency conversion test are shown in Table 2.

Table 1: Voltage regulation test results

Voltage frequency / HZ	Voltage amplitude / V	Current / A
50	24.9	2.05

Table 2 Frequency conversion test results

Voltage frequency / V	50	30	20	75	100
Actual voltage frequency / HZ	50	30	20	75	100
Voltage amplitude / V	24.9	25.1	25.1	25	25.1
Load current /A	2.02	2.01	2.01	1.99	1.99

The converter 1 stabilizes the voltage at 24.9V at 50 Hz. The voltage frequency can be adjusted within 20Hz~25Hz, and the voltage amplitude is stable at 25V. See Appendix 1 for sinusoidal waveforms. The test results show that the design meets the requirements.

B. Energy feedback

Test program

Step 1: Connect the converter 1 in series with the energy feedback device, and measure the voltage waveform of the energy feedback device with an oscilloscope.

Step 2: Press the button to set the output current of the converter 1 to 1A, and measure the output current of the converter 1 with a current clamp.

Step 3: Press the button to set the output current of the converter 1 to 2A, measure the output current of the converter 1 with the current clamp, and measure the current and output voltage of the output of the energy feedback device.

Step 4: Calculate the efficiency of the energy feedback device.

Test results and analysis

Analysis of experimental results: Through the button control, the output current amplitude of the converter 1 can reach 1A, 2A respectively. The test results of the energy feedback link are shown in Table 3.

Table 3 Test results of energy feedback

Power output current /A	Power output voltage / V	Energy feedback device output current / A
0.08	50	0.92

the efficiency of the energy feedback device is:

$$n = \frac{50 - 0.08 \times 50}{50} = 92\%$$

The power of the DC current output is:

$$P = 0.08 \times 50 = 4W$$

The test results show that the output power of the DC power supply is small, and the efficiency of the energy feedback system is high, which meets the design requirements.

CONCLUSION

For single phase full bridge topology of the main voltage source PWM rectifier, the rectifier and the relationship between the steady-state vector control theory is studied. In order to reduce the switching loss, a unipolar modulation switching mode is adopted; in order to make the rectifier have better dynamic and static performance. The experiment proves that the double closed-loop control strategy based on hysteresis current control has the advantages of making the power factor of the grid side close to 1, the voltage of the DC side is stable, and the energy can be fed back.

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