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Design of Microgrid Simulation System

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Abstract. For reasonable deal with the relationship between the public power grid and distributed generation, this design by micro grid simulation system as an object, mainly studies the design method of grid inverter, completed the grid inverter hardware system and control system design, and on the basis of the above work, the micro grid simulation system is designed by simulation analysis and experimental verification.Simulation and experimental results show that the designed system can simulate island operation and grid-connected operation, and has complete functional indexes and higher performance indexes, which verify the correctness and rationality of the designed system.

1. Introduction
The generation of electricity mainly based on fossil fuels has affected people's living environment and physical health, and boosted the rapid development of new energy generation forms such as wind energy and solar energy [1]. In view of the characteristics of vast territory and abundant wind and solar energy in western China, distributed power generation based on the above energy forms has been widely used. However, the large-scale disordered grid connection of distributed power generation equipment will lead to the reduction of power supply quality of the public power grid and even affect its safe operation, and at the same time increase the uncertainty and complexity of the planning and operation of the power grid system [2]. In order to properly deal with the relationship between large power grid and distributed generation, a micro grid technology is proposed [3]. Micro grid is a group of micro power supply, energy storage system, energy conversion device, load, control device and other components of the small power distribution system, with grid operation and island operation mode. The micro-grid simulation system designed in this paper has completed the design of the main inverter and grid-connected inverter for simulating the large power grid, including the design of the main control unit, feedback protection unit, display unit, driving unit, power conversion and filtering unit [4]. It has the advantages of high load adjustment rate, low harmonic distortion and high efficiency [5].

2. System Overall Structure Design
The inverter system is controlled by STC15 series single-chip microcomputer produced by macro crystal. It has three-channel PWM output and 10-bit high-precision A/D conversion, generates SPWM wave to drive circuit, ac and dc signal acquisition circuit, peripheral display interface and keyboard, etc. The system structure is shown in figure 1.

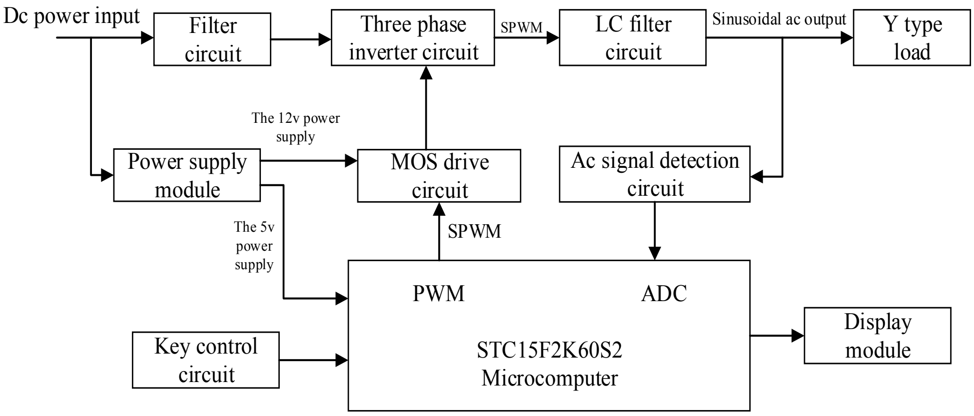

Figure 1. Overall circuit structure block diagram

In figure 1, MOS tube drive circuit generates SPWM wave of a certain frequency by MCU meter checking method. Through the bootstrap circuit of the chip and complementary output of low-end and high-end, two sets of rectangular wave signals with opposite phase can be received and processed within the range of 0V~5V, which are sent to the ADC module of MCU.LCD display circuit and key control circuit. The power part of the system consists of dc filter circuit, three-phase inverter circuit and LC filter circuit.

3. Hardware Circuit Design

Hardware system includes PWM drive circuit, three-phase bridge inverter circuit, ac signal acquisition circuit, power circuit, LCD display circuit, key circuit, etc. The driving circuit and three-phase bridge inverter circuit are the key of the micro-grid simulation system. The design of power supply circuit, LCD display circuit and key circuit in the system adopts the classical circuit.

3.1 Full-bridge Inverter Circuit

The full-bridge inverter circuit selects IRF540N as the switch tube of the full-bridge inverter. The MOS tube has a voltage withstand of 100V and a rated current of 33A, which meets the design requirements. Leakage resistance between the source and 44 m Ω [6], when through the maximum current 2 a, IRF540N lost by only 88 mw power, the power consumption of the whole bridge circuit only 0.5W. Compared with other MOS tubes, IRF540N has excellent technical indicators in terms of voltage resistance, switching on and off, and power loss. The full-bridge inverter circuit is shown in figure 2.

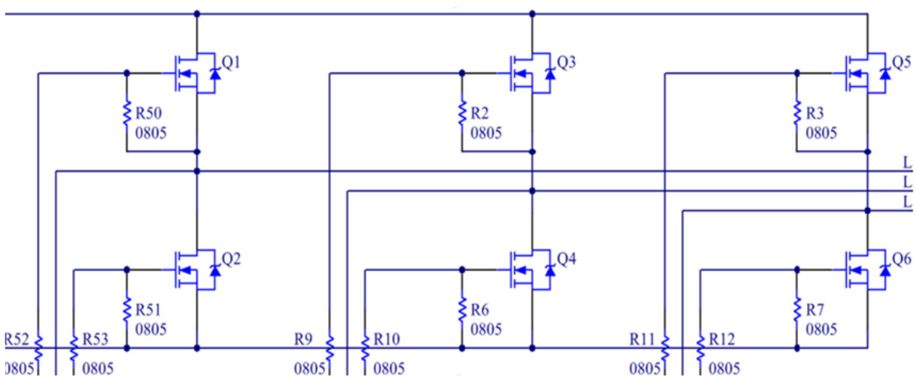

Figure 2. Full bridge inverter circuit

In FIG. 2, six n-channel field-effect tubes are composed of three opposite tubes, which are the core components of the full-bridge inverter circuit. The two switch tubes of the same phase Q1 and Q2 conduct electricity alternately to achieve 180-degree conduction mode. After power on, each MOS tube in the circuit conducts one circuit every 60 degrees, conducts 180 degrees and then turns off. The conduction sequence of the six MOS tubes is Q1 -- Q2 -- Q3 -- Q4 -- Q5 -- Q6 [7]. The conduction mode is to turn off the signal to the fet first, and then send the pilot communication number to the other fet after the fet is disconnected, that is, set a short dead zone time between the two MOS tubes to avoid the two MOS tubes conducting at the same time and affecting the normal operation of the circuit. Finally, by changing the time interval between MOS tube on and off, the output frequency of alternating current is also changed, the input voltage of dc power supply is adjusted, and the amplitude of output voltage is also changed.

3.2 Drive Circuit

The bridge drive circuit composed of IR2104 driver chip can provide a large grid current and output two complementary PWM waves at the same time. The dead zone time can prevent both switch tubes from conducting at the same time to protect the stable operation of the circuit. The driving circuit of IR2104 is used to further simplify the circuit. As long as the parameters of bootstrap capacitance are set properly, the driving circuit can work normally. And the chip has the advantages of high integration, strong anti-interference ability, simple design circuit, strong stability and so on, fully meet the design of the driving circuit. The circuit is shown in figure 3.

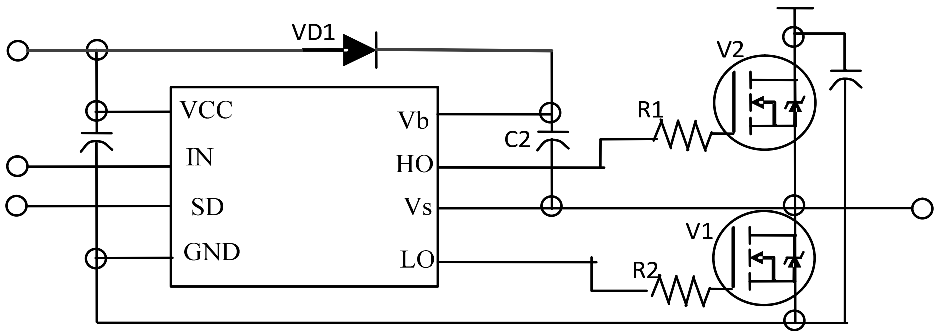

Figure 3. Driving circuit of IR2104

When the chip is powered on, the power supply charges the capacitor through a diode, and the voltage at both ends of the capacitor will quickly reach the power supply voltage. When the low-end fet is conducted, a charging loop is formed between the Vs pin and GND, and capacitor C2 will be quickly charged to the power supply voltage. When the PWM signal changes, IR2104 also changes the output level. At this time, the MOS tube at the low end of the chip is off and the MOS tube at the high end is on. Due to the bootstrap effect of capacitance, the voltage at the high end of the chip will continue to be higher than the source voltage of the upper tube, so that the MOS tube can be conducted in time. In addition, a dead zone time is set inside the chip to prevent both MOS tubes from conducting at the same time and protect the normal and stable operation of the circuit.

4. Software Circuit Design

The main device is designed with C language to achieve SPWM output, key control and screen display. PID algorithm is used to control the output voltage amplitude accurately.

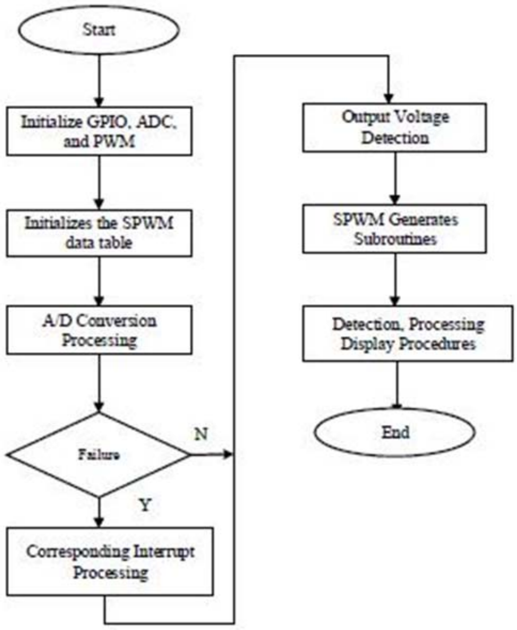

Figure 4. Main program flow chart

4.1 Main Program Design
The main program is the initialization of each submodule, execution of conditional judgment statement, execution of each sub module, and timing execution of interrupt processing. The main program flow is shown in figure 4.

In the main program flow chart, and start the first step to GPIO port initialization, ADC initialization, PWM output initialization, register initialization, establishing the interrupt to scale, through setting all the required initialization value, after completion of initialization, and then perform A/D acquisition subroutine, A/D converter continuous don't ask, don't break to collect data, real-time detection of inverter whether fails, and in the event of A failure to timely treatment, guarantee the safe operation of the system.

4.2 PID Algorithm Implementation
The stability of power supply output voltage is one of the important standards to measure the quality of a power supply. PID algorithm is used to adjust the output voltage proportionally to make the output more stable. The closed-loop feedback control schematic diagram of power supply is shown in FIG. 5.

Input r PID Controller C1 SPWM Regulator C2 t Ouput

h

A/D conversion

Figure 5. PID algorithm control schematic diagram

The PID controller input in figure 5 is the difference between the actual input r and output feedback h, and the obtained value adjusts the size of SPWM under the PID controller to control the output voltage. After sampling the output voltage through the single-chip microcomputer, the size of SPWM is adjusted to make the output voltage tend to be stable. Then, the PID controller can adjust the output voltage faster and more accurately to make the output voltage stable.

After the Laplace transform of each link in figure 5, the transfer function is as follows.

$$U_f(S) = \frac{C(S)}{R(S)} = \frac{U_1(S)U_2(S)H(S)}{1+U(S)U_2(S)H(S)} \quad (1)$$

Let U(S) =U(S) +U_2 (S), and take the derivative of formula 1 to get:

$$\frac{dU_f(S)}{U_f} = \frac{1}{(1+U(S)H(S))} \times \frac{dU(S)}{U(S)} \quad (2)$$

The PID algorithm of U1 controller is expressed as formula (3):

$$U_1(S) = K_P(1 + \frac{1}{K_P S} + K_D S) \quad (3)$$

PID regulation link includes proportional regulation, integral regulation and differential regulation, in which proportional regulation is proportional to the deviation of the reaction system. The integral adjustment mainly improves the zero difference degree, and the differential adjustment makes the adjustment time decrease and the system reaction speed become faster. Through PID algorithm, the power output is more stable and the output voltage error is smaller.

5. Test Data

Y-type pure resistance load was selected as the three-phase inverter load, PSW 80-40.5 was used as the input dc power supply, hp-34401a was used as the voltage and current detection instrument, and the oscilloscope model was gds-1072b.Control the dc input power supply voltage to 41.57v, limit current 3A, test the input and output waveform of three-phase bridge circuit, and test the effective value of the output voltage and current.

5.1 Load Adjustment Rate Test

Dc power supply is used to supply the inverter with a voltage of 51.67v.Disconnect inverter 2, make the inverter work independently, output connected to y-type load, with voltmeter measured output no-load and full-load voltage, respectively, represented by U0 and U2.The grid-connected inverter is controlled to make the two inverters work together. Voltmeter is used to measure the voltage when the current is 1A and the voltage when the current is 3A, respectively represented by U1 and U3.The test data is shown in table 1.

Table 1. Load adjustment rate test data

Number	U0/V	U1/V	U2/V	U3/V
1	24.3	24.2	24.0	23.9
2	24.2	24.1	24.0	23.8
3	24.1	24.0	23.9	23.8
4	24.3	24.1	23.9	23.7
5	24.1	24.0	24.0	23.9
6	24.1	24.0	23.8	23.9
7	24.2	24.1	24.0	23.8

Take the average value of the test data for 7 times and get:U0 = 24.2 V.U1 = 24.1 V.U2 = 23.9 V.U3 = 23.8 V. By substituting the sorted data into formula (5.1) and formula (5.2) respectively, it can be concluded that the load adjustment rate S1 of inverter 1 is 1.25%, and the load adjustment rate S2 of inverter 2 is 0.8%.

5.2 Inverter Efficiency Test

The efficiency of inverter 1 is the output power of inverter 1 divided by the input power of dc power supply. The output voltage and output current of the dc power supply are measured through the voltage and current test instrument, and then the output voltage and output current of the inverter at full load are measured. The test data are shown in table 2.

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Experimental results show that wen inverter 1 works alone, when the input voltage of dc power supply is U1=44V, the input current is I1=2A, the input power P1=U1*I1=90W. The measured output voltage of inverter 1 at full load is U2= 24.0v, the output current is I2=2A, and the output power P1= 83.5w.The calculated efficiency of the inverter is 92.3%.

Table 2. Inverter efficiency test data

Number of measurement	Input voltage /V	Input current /A	Output voltage /V	Output current /A	Efficiency
1	24.0	0.5	13.5	0.48	95.4%
2	30.0	1.0	16.8	0.98	95.0%
3	35.0	1.5	19.1	1.48	93.2%
4	41.6	2.0	22.5	1.98	92.8%
5	45.0	2.0	24.0	2.00	92.3%

6. Conclusion

In this micro-grid simulation system, the design of this micro-grid simulation system is mainly introduced through the design of hardware circuit and the preparation of software. In the hardware circuit, MOS driver circuit, three-phase inverter circuit, output filter circuit and signal processing circuit are introduced. In terms of software, SPWM waves with phase difference of 120 degrees are generated by single-chip microcomputer. PID algorithm and single chip microcomputer are used to stabilize the voltage. Completed the following work:

(1) Completed the hardware system and control system design of grid-connected inverter and micro-grid simulation system;

(2) Completed the simulation and experimental verification of the design system, and analyzed the simulation and experimental results;

(3) Experimental results show that the designed micro-grid simulation system can generate sinusoidal alternating current with a phase difference of 120 degrees, with a frequency of 50Hz, a voltage of 24V, and a current of 2A. The load adjustment rate is less than 1%, and the efficiency is up to 92.3%. The odd harmonic content and even harmonic content are less than the limit value.

7. Acknowledgments

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