Research and Design of a Wind Power Generation Simulation Device

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Abstract: Developing wind power will help to adjust the energy structure, reduce environmental pollution, ensure energy security and achieve sustainable development. The research on low-cost wind power simulation device is of great significance for the training of wind power technicians in colleges and universities. In this paper, a wind power generation simulator is designed, which uses single chip microcomputer as the core controller. The device can use wind driven generator to generate electricity to charge up the battery to supply load, and to supply to the main control circuit without external power. At the same time, the voltage, power and charging state of the battery can be displayed on the display in real time.

Keywords: Wind Power Generation; Hardware Design; Software Design; Control

1. Introduction

As a clean energy source with large reserves and wide distribution, wind energy has gained widespread recognition for its social and economic benefits, and its development prospects are very broad [1]. Wind power generation technology, as one of the main methods of utilizing wind energy, has also become increasingly mature. The economic benefits it generates are approaching those of conventional energy sources, making it highly potential for development [2].

The rapid development and broad prospects of wind power generation have greatly stimulated the demand for talent in this field. However, most research institutes currently lack simple-to-operate, visually intuitive and low-cost wind power generation experimental devices for learning and use [3-4]. Therefore, designing a wind power generation simulation platform for the laboratory holds significant importance for the learning of wind power generation technicians.

The principle of wind power generation is to use wind energy to drive the rotation of wind turbine blades, which then drives a generator to produce electricity [5]. Due to the randomness and intermittency of wind energy, independently operating systems all have energy storage functions. Batteries are an indispensable component, so the battery control circuit is an important part of the wind power generation system [6-8].

Some studies have focused on small wind power generation [9-12], but these studies only covered part of wind power generation and did not develop a complete laboratory simulation device or the design lacks comparison or selection. This paper designs and develops a low-cost and good performance laboratory wind power generation simulation device to meet the needs of learning and research.

2. System Structure

The structure of the wind power generation device designed in this paper is shown in Figure 1, and it has the following functions.

(1) Wind power generation function: The wind blows the blades, driving a three-phase brushless generator to produce three-phase alternating current. The three-phase alternating current is rectified into direct current through a three-phase rectifier circuit. The direct current is then stepped down and filtered by a voltage stabilizing and filtering circuit, with the output voltage limited to within 15V.

(2) Main control circuit: A microcontroller is used as the main control chip to control the entire device.

(3) Self-power supply function: No external power supply is required. The electricity generated by the wind power generator, after being stabilized and filtered, is used to charge the battery. The battery supplies power to the microcontroller through a 5V voltage stabilizing circuit.

(4) Battery charge and discharge protection: The

A/D conversion circuit converts the voltage information of the battery into digital signals and outputs them to the microcontroller. The microcontroller determines the battery status based on the battery voltage and controls whether the overcharge and over discharge protection relay operate according to the battery status. If the battery is neither overcharged nor over discharged, the wind turbine generator charges the battery, and the battery supplies power to the load normally. If the battery is overcharged, the overcharge protection relay operates, disconnecting the wind turbine generator from the battery, thereby stopping the wind turbine generator from charging the battery. If the battery is over discharged, the over discharge protection relay operates, disconnecting the battery from the load, thereby stopping the battery from supplying power to the load.

(5) Display function: The device can display the battery voltage, capacity, and current charging status in real time through a liquid crystal display.

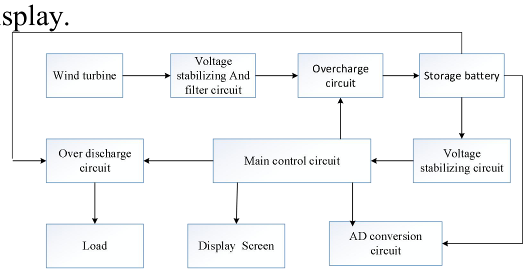

Figure 1. Structural Diagram of Wind Power Generation Equipment

3. Hardware Design

Hardware design includes the selection and testing of equipment such as main control circuit chips [13], batteries, A/D conversion chips, overcharge/over discharge protection circuits, displays, power supplies and generators.

Compared with the STM32F103C8 microcontroller, the high-cost-performance STC89C52 microcontroller was selected as the main control chip.

A 12V battery was selected for its higher universal [14]. The larger the battery capacity, the higher the price, so ultimately a 12V battery with a capacity of 1.3AH was chosen.

In terms of A/D conversion chips, a comparison was made between PCF8591 and ADC0832. ADC0832 is a parallel dual-buffered 8-bit ADC, while the PCF8591 chip is a multi-channel 8-bit successive approximation ADC with an I2C bus structure and an integrated 8-bit single-channel ADC. Compared to ADC0832, PCF8591 has lower power consumption, includes an internal track-and-hold circuit, and most importantly, features an I2C bus structure that allows input and output via serial communication, thereby saving IO port resources. Therefore, PCF8591 was selected as the A/D conversion chip in the design.

Initially, the PNP-type 9012 transistor and NPN-type 9013 transistor were selected as transistors for the overcharge and over discharge protection circuit [15-16]. When the base of a PNP transistor is at a low voltage level, the transistor conducts and the relay engages. Conversely, when the base is at a high voltage level, the transistor cuts off and the relay stops working. When the base of an NPN transistor is at a low voltage level, the transistor cuts off and the relay does not operate. Conversely, when the base is at a high voltage level, the transistor conducts and the relay engages. When the microcontroller is first powered on, all I/O ports will have a brief high voltage level. If an NPN-type transistor is selected, even if the I/O port is pulled low in the software, the transistor will conduct briefly, causing the relay to engage briefly as well. If a PNP-type transistor is selected, this problem of the relay engaging briefly when powered on can be avoided. Therefore, the PNP-type 9012 transistor is chosen to drive the relay in the overcharge and over discharge circuit.

The battery voltage, power level, and charging status are needed to display in the design. The LCD1602 display with low power consumption was finally selected.

For the power supply of the main control circuit, an external 5V DC power source or a power within the device can be selected. By stepping down the battery voltage to power the microcontroller, the device does not need an external power source. The final choice of this system is to step down the battery voltage to supply power to the main control circuit.

DC brushed motors can directly generate the DC power required by the system [17]. Three-phase brushless motors, without collector rings and brushes, have better operational reliability and are easier to maintain [18-21]. Therefore, a generator is initially selected between these two types of motors. After testing both the DC brushed motor (rated voltage 24V, rated power 80W) and the three-phase brushless motor (rated voltage 120V, rated power 30W), it was found that the DC brushed motor has an excessively large starting torque when generating electricity, requiring too much wind force to function, making it unsuitable for wind power generation. In contrast, the three-phase brushless motor has extremely low starting torque. During testing, it was able to generate a voltage of 16V at a wind speed of 5m/s. Therefore, the three-phase brushless motor was selected as the generator for this device.

4. Software Design

As shown in Figure 2, the software flowchart first reads the voltage value obtained from A/D sampling. Then it determines if the voltage is greater than the overcharge threshold. If it is, the overcharge protection relay operates and proceeds to the next process. Otherwise, it checks if the voltage is less than the over discharge threshold. If it is, the over discharge protection relay operates and proceeds to the next process. If not, it proceeds to the next process. Subsequently, the battery capacity is calculated based on the voltage, and finally, the voltage, capacity, and current charging status are displayed on the monitor.

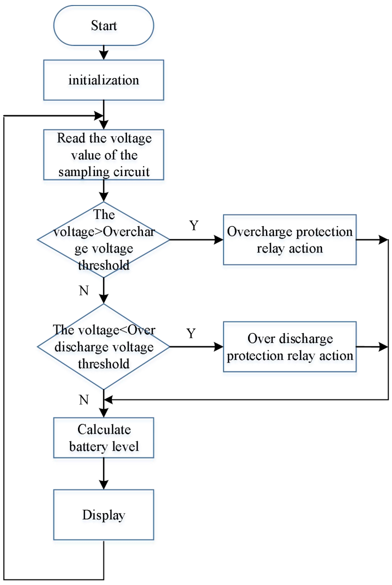

Figure 2. Wind Power Generation Control Flowchart

Figure 3. Physical Diagram of the Device

5. Experimental Testing

The overall physical diagram of the device is shown in Figure 3.

5.1 Device Normal Operation Test

When testing the device, a motor with a working voltage of 12-24V, a speed of 500-1000 rpm, and a fan blade was used to simulate wind energy.

The operating status of the device is shown in Figure 4. The motor blows the fan blades, driving the rotor of the three-phase brushless motor to generate electricity. The LED light in the voltage stabilizing and filtering circuit is lit, indicating that the generator is generating electricity normally. The LCD1602 display shows that the current battery voltage is 12.2V, the power is 67%, and it is charging. The device is operating normally.

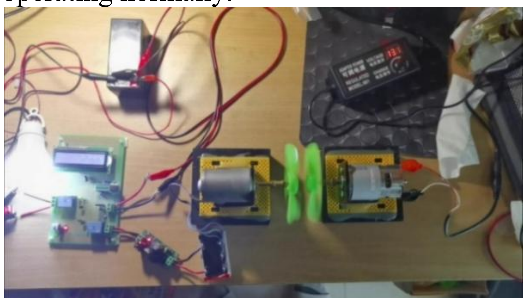

Figure 4. Normal Operation Test Diagram of the Device

5.2 Overcharge Protection Function Test

The overcharge protection function test is shown in Figure 5, with the overcharge threshold set at 14.4V. When the power generation system charges the battery voltage to 14.5V output, the overcharge protection circuit indicator light illuminates, indicating that the overcharge protection relay is operating normally. The charging circuit is disconnected, and the overcharge protection function has been achieved in the device.

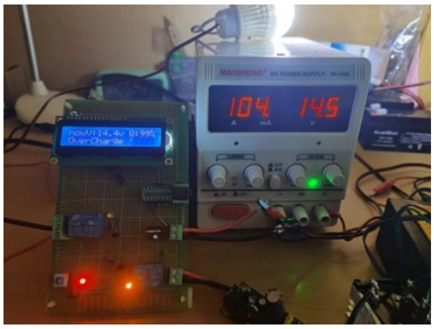

Figure 5. Overcharge Protection Function Test Diagram

5.3 Over Discharge Protection Function Test

The over-discharge threshold is set at 10.6V. When the output voltage of the battery is 10.5V, the LED energy-saving lamp, which acts as a load, does not light up, and the indicator light of the over-discharge protection circuit illuminates, as shown in Figure 6. It indicates that the over-discharge protection relay is operating normally, and the device has achieved the over-discharge protection function.

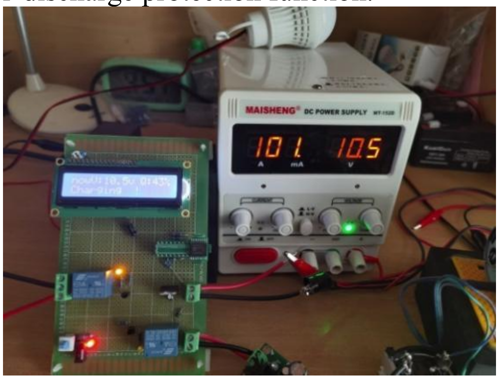

Figure 6. Over Discharge Protection Function Test Diagram

5.4 Sampling Function Test

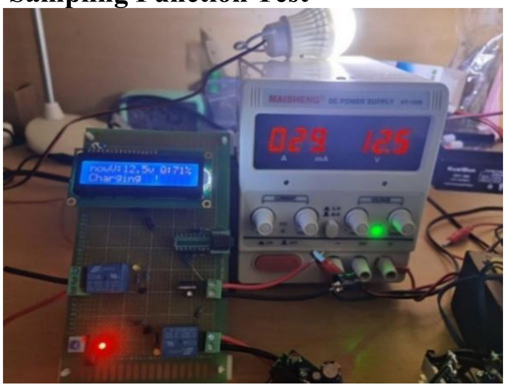

Figure 7. Sampling Function Test

When the measured voltage is 14.5V, the voltage displayed on the screen is 14.4V in Figure 5. When the measured voltage is 10.5V, the voltage displayed on the screen is also 10.5V in Figure 6. In Figure 7, when the measured voltage is 12.5V, the voltage displayed on the screen is also 12.5V. In summary, an error of 0.1V may occur at higher voltages, and this small error is acceptable. Therefore, the sampling result of the A/D sampling circuit is accurate.

6. Conclusion

The device described in this thesis can simulate wind power generation. It has low power consumption and high cost-effectiveness. It can self-power the control system without external power supply. it features battery charge and discharge protection as well as real-time display functions. It can be practically applied in laboratory research. Compared with experimental equipment on the market, this device has a low cost and small footprint.

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