

# Design and Research of Wind Power generation Power Controller\*

Zhijie Tang, Pinglong Liu, Jiali Shen, Jun Luo

School of Mechatronic Engineering and Automation, Shanghai University, Shanghai 200072, China  
tangzhijie@shu.edu.cn, lplfy1992@126.com

**Abstract** - Wind energy is a kind of inexhaustible and clean renewable energy. Wind power system has some characters of simple structure, convenient maintenance and easy management, which gets a lot of attention. This paper analyses the composition and the principle of wind power system. Based on variable speed wind power generation device, a new type of wind power controller that can output stable voltage under the condition of variable wind speed has been designed. The whole bridge rectifier module, step-down transformer module, CPU module, CPU power supply module, brake module of wind power controller are introduced in detail. With the simple structure and convenient maintenance and easy management, the controller has solved output stable voltage effectively.

**Index Terms** - Wind power, Power controller, Variable wind speed, Stable voltage.

## I. Introduction

The 20th century was the era of fossil fuels and the 21st century is the era of renewable energy. As an important renewable energy, wind energy is inexhaustible. When wind energy is converted to electrical energy, it does not produce any harmful gases and waste. It has the characteristics of non-pollution, local materials and no transportation. In recent years, with the development and wide application of control technology and electrical and electronic technology, wind power technology has made considerable progress<sup>[1]</sup>. Wind power becomes the first choice when states consider the development of new environmental friendly energy.

At present foreign wind power technology develops quickly, of which the most advanced is European technology. China is rich in wind resources, but the wind power industrialization process is slow in our country, with certain scale and ability construction of large wind farms in recent years<sup>[2]</sup>. With the increase of wind power installed capacity in power grid and the expansion of the proportion of power grid, it puts forward higher request for security and stability operation<sup>[3]</sup>. The volatility of wind energy, not only influences the quality of the grid, but also reduces the efficiency in the use of the wind turbine. Therefore the use of advanced, high reliability and safety of wind power generation technology is very necessary. A key technique that names supply controller design research is involved. Study of wind power controller, domestic and foreign development present situation as follows:

Zhao Qiang<sup>[4]</sup> based on the research of the characteristics of the independent power system, puts forward a kind of

control strategy by adjusting the electromagnetic torque, rotational speed regulation power. Joining the electronic regulator, he realizes the system operate steadily.

MONICA CHINCHILLA, SANTIAGO ARNALTES<sup>[5]</sup> etc. put forward a kind of power management controller, according to variable wind speed problem. The controller can achieve good mediation of variable wind speed.

Huang Kai, Zhong Qing<sup>[6]</sup> design a kind of converter controller based on IEC61850. It achieves the enhancement to the network function of the controller and lays a foundation for the coordinated control of the distributed power between.

Wang Yang, Cheng Li<sup>[7]</sup> using permanent magnet synchronous wind power generation system (PMSWG), design non-controlled rectifier with pulse grid modulation (PWM) converter structure. Through experimental verification, the designed system is easy to use independently, and is easy to be incorporated into the site.

Using chip LM5116, this paper can use it for different input voltage, to realize synchronous step-down and get stable voltage output. On the control, by using the ATmega32 16 AU and chip LM5116 collaborative control, the controller realizes the stable voltage output and the control of wind generator brake etc. This paper firstly introduces the composition of wind power system. The second part focuses on the wind power generation system schematic diagram, and analyzes main modules, such as chip LM5116, brake etc. The third part analyzes the power controller programming. Finally according to the present research situation, we have a summary of the full text.

## II. Wind power system

Wind power system is divided into two categories: one is a grid-connected wind power system, and the other is independent wind power system. In this paper, the main research object is independent wind power system. Because of the instability and randomness of the wind power output, the system needs to configure the charging device. At present, the most common device is battery charging device<sup>[8]</sup>.

### A. Basic components

Independent wind power system usually consists of wind turbine, generator, storage battery, inverter, controller, tower of composition, and the diagram is shown in figure 1.

\* This work is partially supported by the National Natural Science Foundation of China (No.51005142).

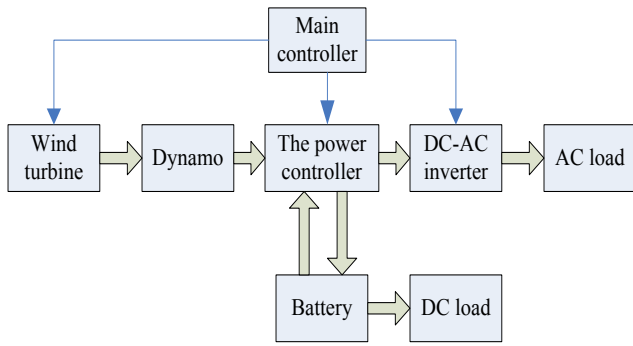


Fig. 1 Independent of wind power system diagram

Wind turbine is mainly used to capture wind and convert it into mechanical energy. Wind turbine is generally combined into three blades. Generator is the key to the implementation of wind energy into electrical energy conversion devices. In recent years a kind of variable speed wind turbine develops. When rotate speed of the rotor changes with wind speed, the frequency of alternating current changes [9]. Controller is to ensure the normal operation of wind power generation system and an important part to protect the safety of the whole system. Tower supports wind turbines to a certain height to gather wind power. Battery guarantees electricity users to access to electricity in no wind. During the windy, when wind power has increased dramatically, the battery can absorb redundant wind. At present, the 12v-48v lead-acid battery is mainly adopted. Inverter is a kind of the device that converts direct current (DC) to alternating current (AC).

### B. Electric-generation principle

Firstly, wind turbine captures wind energy and converts it into mechanical energy. And generator turns mechanical energy to electrical energy. Due to random wind speed and direction, the frequency of alternating current (AC) also changes. Through wind power controller, variable frequency and variable voltage AC is rectified into stable direct current. Produce direct current (DC) for electric power. At the same time, the excess electricity is stored in the storage battery. When wind turbine cannot provide enough power, battery provides direct current (DC) and drives a DC load. If it is need to drive AC load, the inverter converts direct current (DC) to alternating current (AC) for the power.

## III. Hardware circuit design

In the independent wind power system, control system plays an important role to ensure the normal operation and protect the safety of the whole system. In the control system, main controller has the wind turbine control orientation, real-time solution line, adjusting the rotational speed of the fans and coordinate control of the whole power generation system. The power controller has stable output voltage, reasonable distribution of electricity, reasonable control for the storage battery charging and discharging and "brake" etc. In this paper, we study the power controller, using the chip LM5116 and ATmega32 16 AU chip. And we plus full bridge rectifier

module, voltage comparator module, battery etc. together. The chart is shown in figure 2.

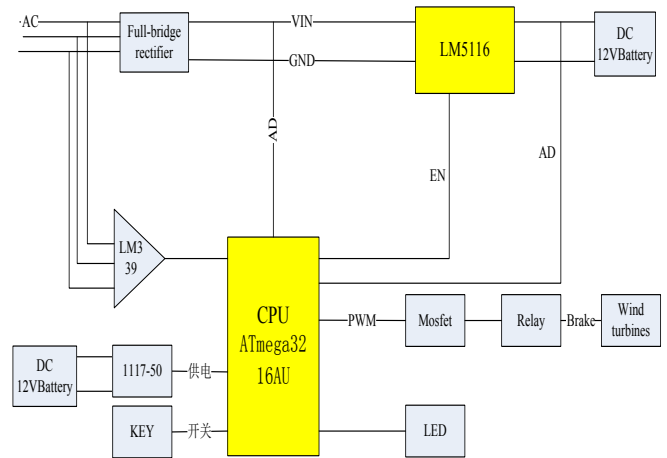


Fig. 2 The power controller structure

### A. Step-down transformer selection

Chip LM5116 was chosen as the step-down transformer in this paper. It achieves stable output voltage for the variable input voltage. Chip LM5116 is a synchronous step-down controller and can be used in high voltage or a wide range of different input voltage step-down. Its working range can be 100v. The chip can be driven high side and low side MOSFET tube and realizes the voltage control. The chip is the TSSOP-20 encapsulation. Its bottom is exposed, so that the heat dissipation is good. All in all, we select LM5116 as a step-down transformer. Circuit diagram is shown in figure 3.

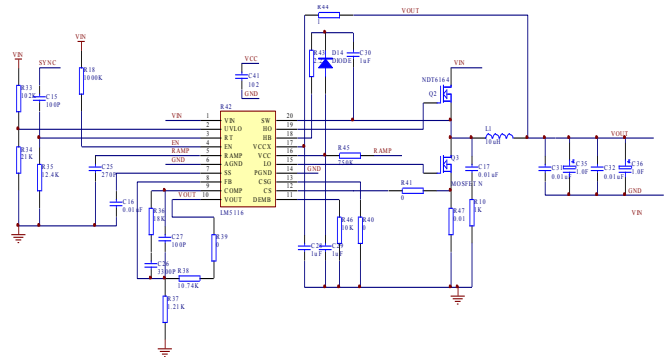


Fig. 3 LM5116 step-down circuit diagram

This controller is set up for the 12v stable output voltage. According to chip LM5116 instruction,  $R_{37}$  and  $R_{38}$  set the output voltage level, the ratio of these resistors is calculated from:

$$\frac{R_{38}}{R_{37}} = \frac{V_{OUT}}{1.215V} - 1 \quad (1)$$

$R_{37}$  is typically 1.21k $\Omega$  for a divider current of 1 mA. The divider current can be reduced to 100  $\mu$ A with  $R_{37}=12.1k\Omega$ . For the 12V output design example used here,  $R_{37} = 1.21k\Omega$  and  $R_{38} = 10.74 k\Omega$ .

### B. Control chip select

For this power supply controller, CPU is the core of the control panel module. It directly determines whether the performance of the wind power control system is good or bad. Selecting the chip, we mainly consider from the system power consumption, processing performance, and peripheral interface etc. several aspects. ATmega32 16 AU has eight AVR with a high performance and low power consumption microprocessor advanced RISC structure. ATmega32 16 AU has rich external ports, such as four channel PWM, 8 lines and 10 bit ADC, eight single-ended channels, 32 programmable I/O, external signal capture, etc. The chip is the QFP44 encapsulation and circuit diagram is shown in figure 4.

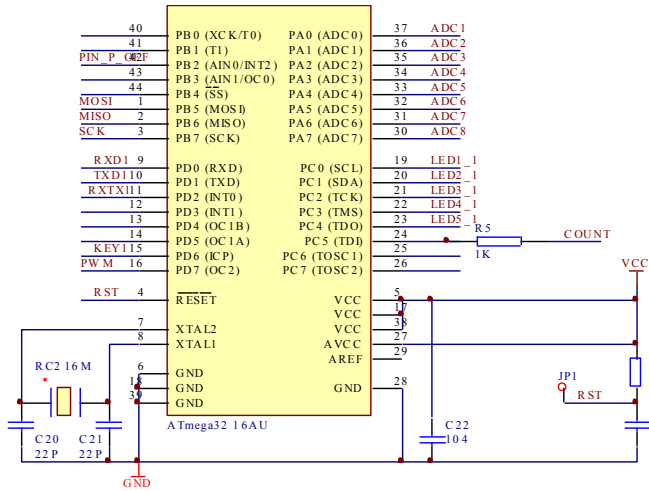


Fig. 4 CPU circuit diagram

### C. Main module design

#### 1) Full-bridge rectifier

Because the output voltage of the wind power generators is three-phase AC power. And the frequency changes with wind speed variation. The role of the whole bridge rectifier is to convert the three-phase alternating current (AC) to direct current (DC) for chip LM5116. The circuit diagram is shown in figure 5. Considering that the work voltage is larger, we use IN4007 diode. The Capacitances have the function of bypass and noise reduction.

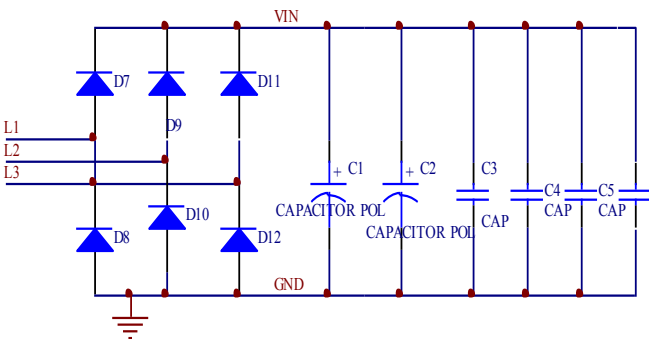


Fig. 5 full-bridge rectifier circuit diagram

#### 2) CPU power supply module

The working voltage of ATmega32-16 AU is 4.5-5.5 V, but the battery voltage is 12 V. To supply the power for CPU, power supply module is essential. In this article, the chip 1117-50 buck is used and circuit diagram is shown in figure 6. Chip 1117 is available in adjusting 1.8V, 2.5V, 2.85V, 3.3V and 5V. Its footprint is SOT-223.

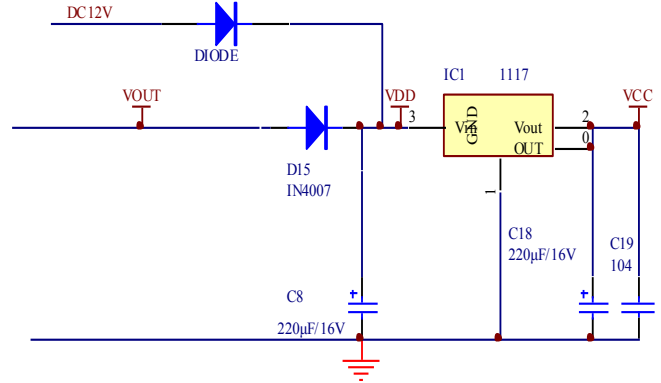


Fig. 6 Power supply module

#### 3) Brake module

Once impeller device is installed, as long as there is wind, it will turn. How to stop must be solved, so a "brake" device is essential. When wind speed is too big or there are sudden emergencies, the control system has the function of "brake", which can protect the system from damage. First by the PWM signal from the CPU, the transistor, MOSFET, relay, an electrical current drive the brake device and the impeller stops. Brake module circuit diagram, as shown in figure 7.

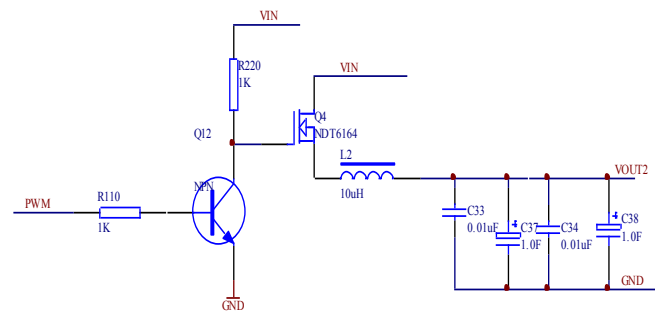


Fig. 7 Brake module circuit diagram

### IV. The power controller program

Software design is mainly through software programming to reset for each register for event manager interrupts and port module. The main program of the power controller achieves initialization, the input analog signal A/D conversion, brake handle, interact with LM5116, stable voltage output, storage battery charging and discharging control etc. functions. The main program flow chart is shown in figure 8.

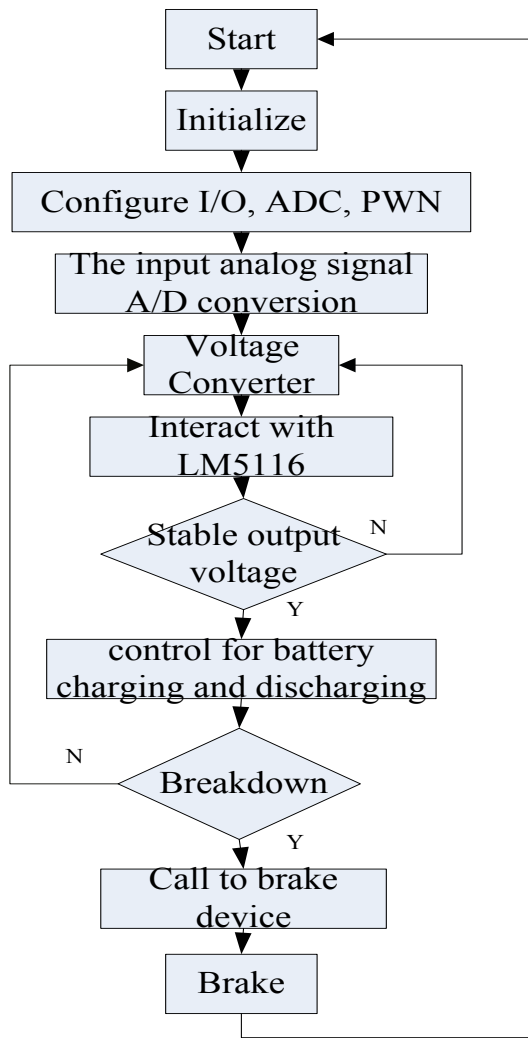


Fig. 8 Main program flowchart

## V. Conclusion

To solve that variable speed wind power generation device needs a stable output voltage, we designs a new type of wind power controller. The controller realizes stable output voltage of 12V. LM5116 can allow wide input voltage range and has stable output voltage, using coordination control between chip LM5116 and chip ATmega32-16 AU. Chip ATmega32-16 AU has the rich external port such as ADC,

PWM. When there is unstable current from the generator, one part is rectified to direct current (DC) through full-bridge rectifier. The chip LM5116 realizes stable 12V output and the electricity is stored in the battery. At the same time, other part of the electricity flows through the LM339 voltage comparator and is transmitted to the chip ATmega32-16 AU. Through ADC port, the chip connects with the chip LM5116 and they achieve the output voltage of 12V. The chip also has an emergency "brake" function, so as to protect the safety of wind power system. This power source controller has simple structure, convenient control, low cost, easy maintenance and other characteristics. It can be widely used in wind power generation system.

## Acknowledgment

The authors would like to acknowledge National Natural Science Foundation of China (No.51005142), the key project of Chinese Ministry of Education (No.210071), Shanghai Municipal Science and Technology Commission Project (No.10170500400).

## References

- [1] S. Bian, Y. He. "Study on the Technology of Variable-speed Constant-Frequency Wind Power Generation," Zhejiang University, 2003.
- [2] Y. Chi, S. Zhang, J. Li, "Wind power development at home and abroad," Productivity Research, vol.18, pp. 74-76,2008.
- [3] Z. Ni, X. Cai, "Design and realization of main-controller for doubly fed induction generator," Shanghai Jiao Tong University, 2008.
- [4] Q. Zhao, "Research and design of a power-balance controller in stand-alone wind energy generation system," Energy Conservation., no.3, pp. 36-38, 2006.
- [5] M. CHINCHILLA, S. ARNALTES, J. CARLOS BURGOS, "Control of Permanent-magnet generators applied to Variable-speed Wind-Energy systems connected to the grid," IEEE Transactions on Energy conversion, vol.21, no. 1, pp. 130-135, 2006.
- [6] K. Huang, Q. Zhong, "Interconnection inverter controller of distributed generations based on IEC61850," Power System Protection and Control, vol.41, no. 6, pp. 123-127, 2013.
- [7] Y. Wang, L. Cheng, "Research on Small and Medium-Sized Wind Power Source Suitable for Rural Grid," Journal of Anhui Agri. Sci. vol.39, no.27, pp. 17075-17078, 2011.
- [8] L. Gong, Y. Li, "Design of controller system of the wind generation system," Changchun University of Science and Technology, 2012.
- [9] N. R. ULLAH, T. THLRINGER, "Variable speed wind turbines for power system stability enhancement," IEEE Transaction on Energy conversion, vol. 22, no. 7, pp. 52-60, 2007.