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Research on the Application of Single-Chip Microcomputer in Wind Turbine Control

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Abstract: As an important source of clean and renewable resources, the importance of wind power generation is increasing under the background of the theme of "environmental protection" in the new era. The efficiency of wind power generation is mainly affected by the reliability and performance of the power generation system, so it is necessary to use a single-chip microcomputer system and an intelligent algorithm to assist control, so as to improve the performance of wind power generation. Based on this research background, this paper expounds the working principle and basic characteristics of a single-chip microcomputer, summarizes its application advantages in wind turbine control, and puts forward the application practice strategy of a single-chip microcomputer in a wind turbine control system, which provides important assistance for the upgrading of the wind power system.

Keywords: Microcontroller; Wind power generation; Generator control

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1. Introduction

Wind power generation is a process that relies on wind energy to drive an impeller, so as to convert mechanical energy into electrical energy. In recent years, with the rapid development of wind power technology in China, the capacity of wind turbines continues to rise, up to several megawatts, which has higher requirements for generator control. Therefore, in order to stabilize the operating efficiency of wind turbines, it is necessary to establish an accurate motor control system to adjust their speed and monitor any faults in real time. On this basis, the single-chip microcomputer with high integration and remarkable operation speed shows good application value, especially with the assistance of an intelligent algorithm, which can provide multiple guarantees for wind turbine control.

2. The working principle of the single-chip microcomputer and its characteristic analysis

2.1. Working principle

Microcontroller is a small chip that integrates CPU, RAM, ROM, clock generator, input and output interface,

and other components, which can realize multiple functions such as microprocessing and control. The working principle of a single-chip microcomputer is mainly reflected in two aspects, one is the execution process of instructions. The instruction fetch–decode–execute cycle is the cycle mode of its work. The MCU can complete the instruction reading through ROM, decode through CPU, and control the arithmetic unit or timer and other modules to execute instructions according to the instruction [1]. The interrupt response mechanism is one of the working mechanisms of the microcontroller, which means that when an external event triggers the interrupt request, the CPU can pause the task, so as to achieve the effect of an interrupt service program. Bus architecture is the structure of the single-chip microcomputer, generally using data and instructions separate storage way, which can effectively improve the efficiency and level of parallel processing.

On the other hand, the working principle of a single-chip microcomputer is also reflected in the cooperative work of core function modules. One is sensor data acquisition, for example, in the wind turbine control system, the SCM ADC module can collect a real-time wind speed signal, and the sampling rate can reach up to 1Msps [2]. The second is the PWN output control. MCU can use the timer to generate a PWM wave. By adjusting its duty cycle, you can realize the effect of adjusting the motor speed.

2.2. Characteristic analysis

2.2.1. Small size

Microcontroller, as a highly integrated chip, small size as its significant feature; only through a single chip can it achieve a complete micro control function. On the one hand, small size reduces resource consumption and can compress manufacturing costs; on the other hand, it can also obtain better anti-interference performance, and then improve its self-protection effect, even in the wind power system can still complete its control function [3].

2.2.2. Low power consumption

Compared with the traditional central processing unit, the single-chip microcomputer not only has a smaller size, but also has significantly lower power consumption characteristics. On the one hand, the circuit structure of the single chip is more sophisticated, on the other hand, the technology level is higher, so it often only needs a few milliampere level of static working current. Taking an 8-bit MCU chip as an example, when it is working at 4~16MHz frequency, the core supply current of 5~15mA can support its operation [4].

2.2.3. Strong anti-interference ability

A single-chip microcomputer can be used in the more harsh environment; the key is that it has good anti-interference characteristics. Compared with the traditional microprocessing system, the single-chip microcomputer has higher integration, a simple structure, and concentrated modules, and is not susceptible to external noise, magnetic field, and other interference.

3. The application advantages of a single-chip microcomputer in wind turbine control

3.1. Accurate generation rate and power control

In the wind turbine control system, generation rate and power control are the keys to maintaining stable power generation performance. The advantage of a single-chip microcomputer not only lies in having good control function, but also has the advantage of accurate control, which can improve its processing and reaction speed, so

as to achieve the effect of three-dimensional control. Specifically, the microcontroller is with the aid of wind speed loop to achieve the purpose of control wind turbine rotor speed, and in the process, the generator can be detected and acquisition of information such as current, voltage, frequency, data, and according to the data accurately adjust motor excitation current, to achieve timely adjust the effect [5] of the magnetic field. In addition, the microcontroller has the advantages of an algorithm and process for precise control. On the one hand, the MPPT algorithm can be used to achieve precise control, such as the disturbance observation method to adjust the generator output voltage with a 0.1V step, which can dynamically analyze the maximum power point. For example, the fuzzy logic optimization method can establish a function model according to the wind speed, pitch angle, and other parameters of the wind power system, so as to reduce the fluctuation and variation of power. On the other hand can realize accurate control by a dynamic load matching process, such as Buck-Boost circuit can be regulated with the help of PWN DC-DC converter, to ensure that the battery can be adaptive charging voltage [6].

3.2. Significant fault monitoring and processing capabilities

In the wind turbine control system, the microcontroller has the advantage of improving the level of fault monitoring and processing. Firstly, the control system can monitor the working temperature, vibration frequency, oil pressure, and other data of the generator in real time through sensors, so as to grasp the working state of the transmission system in real time. In the process, when the data collected by the sensor appears out-of-limit signal, abnormal data, or fault alarm, the microcontroller can automatically make a judgment, and carry out protective control of the generator set according to the algorithm logic. The control means include stopping, braking, alarming, etc., which are important means [7] to ensure the safety of the system. Specifically, the single-chip microcomputer has the advantage of multi-parameter real-time diagnosis. For example, the Hall sensor can detect the speed of wind power generation with an accuracy of ±0.5%. The PT100 temperature sensor can detect the temperature state of the wind turbine. For example, through the dual protection mechanism, the overvoltage rating and the overcurrent rating can be set. When one of them is triggered, the electronic brake and the mechanical brake can be automatically executed, and the response time can be limited to 50 milliseconds [8]. Secondly, the microcontroller can also assist the system to collect fault information, record historical operation data, and establish a fault analysis model through data storage, classification, and statistical identification, so as to form a fault knowledge base, and identify the early fault characteristics through the FFT algorithm. When there was a similar failure again, it can be handled automatically by the system control or automatic feedback fault codes, a fault processing scheme for staff.

3.3. Flexible expansion of function modules

SCM has modular structure characteristics, therefore can not only flexible allocation of resources, but also can according to demand to expand its function modules, so set used in wind turbine control system the advantage of easy to extend and maintain. SCM usually shows the characteristics of distributed control. According to its control functional requirements, set up different control modules, which will complete the control task is divided into different tasks [9]. For example, in the wind turbine control system, the main function modules are divided into motor control, converter control, wind field monitoring, and other different units, and each unit can be controlled collaboratively by the MCU CPU. In this system, when a module fails, it will not directly affect other modules, so it is easier to locate the fault and carry out repair and maintenance. On this basis, when the wind power system needs a new control function, a new control unit can be added to the MCU to achieve the control effect. In addition, the microcontroller can also realize wireless remote monitoring, such as uploading data with

the help of ESP8266 module, and remotely viewing the running status through Modbus-TCP protocol. At the same time, the microcontroller can also realize the expansion effect of edge computing, especially with the aid of an AI coprocessor to implement local fault diagnosis and reduce the dependence [10] on cloud assistance.

4. Application practice of single-chip microcomputer in wind turbine control system

4.1. Monitoring and control of wind speed and direction

4.1.1. Real-time monitoring of wind speed and direction

In the detection of wind speed and direction, the microcontroller can be controlled and processed by a special module. On the one hand, through ultrasonic anemometer, cup anemometer, wind direction meter, and other equipment, the wind speed and direction at the wheel height can be accurately measured, which is used as a reference for controlling the motor. For example, the ultrasonic anemometer can transmit data to the microcontroller through the UART, and the analog signal data can be digitized and analyzed by feature extraction, so as to accurately calculate the wind-related parameters. Single-chip microcomputer can be processed, on the other hand, the wind speed and direction of data transmission to the motor control unit, in the module can be pre-set wind electrical characteristics model analysis of real-time wind power generator unit operation state, and send instructions to perform when need to adjust the unit module, including motor inverter and regulator, etc. [11]. In the process, a single-chip microcomputer can also through Kalman filtering noise reduction, to eliminate the turbulent interference, and reduce wind velocity measurement error.

4.1.2 Adjust the blade angle

The microcontroller can not only monitor the wind speed and direction in real time, but also adjust the blade angle of the wind turbine according to the corresponding data, and then adjust the pitch angle of the blade paddle in real time through precise driving to ensure that the rotor speed and power of the wind wheel achieve the best matching effect. The PG card is the core module of the integrated multi-channel high-power drive unit in the microcontroller, and it is also the key to providing energy for the execution unit of the variable pitch system. So in the MCU application, on the one hand to collect the information such as wind speed and direction, on the other hand, to build the blade angle control model, and based on MPPT algorithm for computing, real time to determine the maximum wind energy utilization pitch angle information, and then through the PWM control signal drive servo motor, with the help of closed loop stepper motor to adjust blade angle, The response time can be compressed to less [12] than 200 milliseconds.

4.2. Generator speed and power control

4.2.1. Control the generator speed

Single-chip microcomputer in the wind turbine control, but also real-time monitoring and collection of rotor mechanical speed, so that through the converter system can be effective, accurate, real-time control of motor speed, to provide a guarantee for the stable operation of the unit, to maintain the effect of high efficiency operation. On the one hand, the microcontroller can collect data accurately and at high speed through the acquisition and measurement module. After the data processing, denoising, and analysis of the photoelectric encoder and Hall sensor, the real-time mechanical speed data [13] of the wind turbine rotor can be obtained. On the other hand, the single-chip microcomputer can analyze the data set, fit it with the speed curve preset by the model, calculate the

deviation between the real-time speed and the optimal speed according to the control algorithm, so as to adjust and control the signal through the converter, accurately drive the motor to adjust the speed, so that it can maintain operation at the optimal speed point.

4.2.2. Stabilize the speed to improve system efficiency

In the wind turbine control, the microcontroller can not only control the speed of the generator, but also control its operating power by stabilizing the speed, and further improve the system efficiency. On the one hand, through the PID speed control algorithm, the deviation between the rotor speed and the model speed can be calculated according to the control model and the gain parameters, so as to reduce the error through the control signal and achieve the effect [14] of stable speed. On the other hand, when the external factors such as wind speed and wind direction change, the speed control controller can also calculate the control amount according to the difference between the actual parameters and the simulation effect, so as to ensure that the speed is always close to the optimal point.

4.3. Fault monitoring and protection

4.3.1. Monitor temperature, vibration, and other parameters

The single-chip microcomputer has the function of multi-module work and management control at the same time, so it can implement real-time monitoring of temperature, vibration, and other parameter data of multiple working parts in fault monitoring. Specifically, it can simultaneously cover the temperature of the generator set, the temperature of the main bearing, the oil pressure, and the vibration acceleration of the gearbox. At the same time, the MCU can also establish contact with the intelligent fault recognition system, according to the relevant data parameters, into the temperature rise curve, eddy current spectrum, vibration waveform, and other intuitive forms, and then determine whether there is an abnormal situation, so as to achieve the effect of fault monitoring. When abnormal conditions are detected, the microcontroller can react and make automatic protection commands within 10 milliseconds, and achieve the effect of protecting the unit by limiting the power or stopping the machine.

4.3.2. Intelligent judgment and early warning

With the development of artificial intelligence technology, single-chip microcomputers can also establish a linkage with AI, thus implementing intelligent fault detection evaluation and early warning. Such as motor running through the analysis of the machine learning history data, and modeling LSTM neural network is used to change the equipment parameters, when there is characteristic deviation monitoring data and model, the system can quickly analyze the fault type, area, content, and maintenance advice [15] is given.

5. Conclusion

To sum up, the application of a single-chip microcomputer in wind turbine control has important value; it can not only accurately detect the speed, power, temperature, and other parameters, but also can achieve stable, real-time, and efficient control effects, thus greatly improving the operation efficiency of the wind turbine. At the same time, the microcontroller can also, through the parameter collection and fault prediction mechanism, provide a scientific guarantee for the wind turbines and stable operation, and through the scheduling wind generator control module, an intelligent decision-making system science to ensure wind turbines can be more efficient, economic, and stable power generation.

Disclosure statement

The author declares no conflict of interest.

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