Design and Implementation of the Intelligent controller for Electric Ship

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Abstract. As an important device in the power system of electric ship, the intelligent controller plays a key role in improving the real-time monitoring and reducing external hard-wire connections. This article introduces the design and implementation of the intelligent controllers which based on ARM controllers, the controller use STM32 series microcontrollers based on the Cortex-M3 core as the core controller, design IO conditioning circuits, GPIO conditioning circuits, and network communication circuits and so on. Also the article carry out the controller testing and the real ship application. The equipment has the characteristics of high reliability, miniaturization and modularization. The successful development of this equipment has improved the degree of automation of electric boats greatly, and has a positive effect on fault monitoring and fault analysis of the power system of electric ship.

1. Introduction

With the continuous improvement of emission requirements in rivers, lakes, ports, electric ship has gradually received industry attention as a new type of power vessel for its silent, environmental protection and zero emissions. Tourist ship in inland rivers and lakes have always been favored by consumers. The use of electric ship has better quietness, environmental protection, and is more environmentally friendly, allowing passengers to have a more comfortable experience[1].

The control system requires real-time monitoring of the status of the main power system equipment such as the battery system, DC power distribution system, and propulsion system. From the bottom of the equipment to the equipment and then to the whole system, the control system is used to conduct real-time status assessment and evaluation of the power system equipment. The control system for Fault diagnosis, and optimize the system control strategy according to the real-time status, to realize the reliable, efficient and stable operation of the pure electric power system. Therefore, as its core component, the intelligent controller includes digital signal acquisition, analog signal acquisition, temperature signal acquisition, fieldbus communication, high-speed network communication, etc. This article designs an intelligent controller with multiple interfaces with fast calculation speed, the article has been completed the design of the controller and complete the corresponding functional tests, the controller can meet the needs of the electric boat for the control system.

2. The Design Of Intelligent Controller

The intelligent controller is mainly for the signal collection and judgment of the battery systems, isolation/load transformers, inverters, propulsion motors and other equipment. On the one hand, the signals of the equipment are sent to the centralized monitoring station for real-time monitoring by
communication. When the value exceeds the alarm value set in the centralized monitoring station, the centralized monitoring station will perform alarm processing. On the other hand, when the equipment’s status exceeds the load of the system, the intelligent controller will issue instructions for the inverter and propulsion motors. Such as power limitation, shutdown processing, deceleration and other operations. By using the intelligent controller, the fault point can be quickly and effectively located when real-time monitoring is running, ensuring the normal operation of the equipment. In this article, the intelligent controller processes acquired the temperature and water leakage alarm signals of transformers and motors, and exchanges part of the signals of the frequency converter, and sends the acquired signals to the centralized monitoring station through industrial Ethernet. At the same time, it carries out intelligent auxiliary decision-making and other controls to ensure the normal operation of the equipment[2].

The main technical parameters of this intelligent controller are as follows:

1. Power supply: 24V power supply.
2. Digital signal input: passive contact, supporting up to 36 channels.
3. Digital signal output: passive contact, supporting up to 36 channels.
4. Temperature signal input: 3-wire system, supporting up to 16 channels,
5. Analog signal input: 4-20mA or 0-5V, supporting up to 16 inputs.
6. Analog signal output: 0-5V, supporting up to 8 channels.
7. Fieldbus communication: CAN, RS485, RS232
8. High-speed network communication: Ethernet communication, support MODBUS TCP, TCP/IP protocol.

The basic configuration of the intelligent controller is composed of a CPU board, a signal conditioning board, a GPIO conditioning board and a network communication board. At the same time, temperature acquisition boards, FPGA expansion boards, optical fiber expansion boards and backplanes can be configured according to actual needs.

1. CPU board

The CPU board is the core part of the control hardware. The CPU uses an ultra-low power STM32 microcontroller. The processor has high performance, high reliability, and low cost. As the processing core of the controller, it completes logic control, signal acquisition and communication. And other functions[3]. ARM chip STM32F103VET6 is used as the control core of the entire module, using its data bus to control ADC, DAC, SRAM, and Ethernet chips on the board; using IO pins to control PWM signals and IO singals; using interrupts Pins receive external interrupt/fault input; using capture pins to receive external pulse input; also providing CAN, RS-485, RS-232 bus communication.
interfaces. The CPU board can realize vector control and other complex control algorithm calculations, complete digital signal acquisition, analog and temperature signal acquisition, system protection, communication with the computer and other functions.

(2) Signal conditioning board

The signal conditioning board completes the functions of analog input and analog output, mainly including voltage and current signal detection, fault judgment and alarm functions. The conditioned data is sent to the external ADC of the CPU board for sampling, and the fault is detected through the SPI bus to the CPU board. Using 16-channel 12-bit successive approximation ADC peripherals, the A/D converter of each channel can be executed in single, continuous, scan or discontinuous mode. The ADC result can be stored in a 16-bit data register in a left-justified or right-justified manner. Since the acquisition support range of ADC in STM32 is 0~VREF, the reference voltage in this article is 2.5V. Therefore, it is necessary to extend the external circuit to support 0-5V or 0-20mA input analog signals. At the same time, to ensure the stability of the acquisition, a high-precision operational amplifier is used in the analog circuit, and a filter module is added to filter out the power frequency. The interference of signals and high-frequency signals ensures the reliability and stability of acquisition. The analog output conversion module mainly completes the output of analog signals, generates a 0-5V voltage signal through the DA module, and converts the 0-5V signal into the required 4-20mA signal through TI's voltage current converter XTR111[4].

(3) GPIO conditioning board

The signal conditioning board completes the functions of digital input and digital output, and performs optocoupler isolation and amplification of the digital signal from the CPU board to drive external indicators and other loads; at the same time, it performs optical Coupling isolation and filtering processing. The digital input module use optocoupler TLP521 isolation circuit, TLP521 is widely used in industry. TLP521 has high isolation voltage, small size, and high cost performance. The GPIO conditioning board supports up to 36 channals. The digital output module uses the relay module, which supports up to 36 channels, which is completed by TLP521 optocoupler with ultra-sensitive and highly reliable relay HFD23.

(4) Network communication board

The network communication board fulfills the requirements of the field bus required by the ship, mainly including CAN communication and RS485 communication. The field bus communication method has advanced features, and is particularly suitable for multi-device and multi-terminal communication; it has the advantages of good anti-interference and fast transmission speed. The CAN communication module uses the dedicated CAN transceiver chip TJA1040 to complete the CAN communication function. STM32 has a variety of internal communication interfaces, which can support up to 5 UART interfaces. The article uses the communication interface chip to expand 1 485 communication interface and 1 232 communication interface. At the same time, the chip and communication interface chip are also unique to the digital isolator ADuM1412 performs interface isolation. ADuM1412 uses ADI's iCoupler technology, which integrates CMOS devices and single-chip air-voltage transformer technology. It has a small size, good nonlinear transmission, and a wide range of applications.
3. Test Of Intelligent Controller

The intelligent controller has been successfully applied to a certain type of inland river electric ship. It can complete real-time monitoring of transformers, motors, frequency converters and other equipment, and can provide real-time alarms and real-time control of some signal quantities. To ensure the reliability of the system, the industrial-grade electronic equipment with high integration, strong anti-interference ability and low power consumption is adopted at the beginning of the design. At the same time, the three-proof material coated on the surface of the printed board meets the environmental requirements of ship regulations. Each module in this article has a self-protection function, which can protect against abnormal conditions during system operation. The acquisition module of the auxiliary machine in this article can realize the maintenance effect by only replacing the module. The whole is also based on the idea of modular design. The intelligent controller supports communication and some hard-wired connection methods, which is convenient for the expansion of equipment. It has great advantages and strong applicability in the industrial field.

4. Conclusion

This article designs an intelligent controller based on the ARM core. The intelligent controller adopts a standardized design and can be expanded as needed. The intelligent controller can meet the needs of electric boat monitoring and control, and has the characteristics of high integration, safety, reliability, intelligence, and miniaturization. The successful development of this equipment has greatly improved the degree of automation of the electric ship monitoring system, and has a positive effect on the fault monitoring and failure analysis of the electric ship power system.

References

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