Design Method of Local Control System Centred on IOT Technology

Jianbao Liu1*, Feng Zhou2 and Xinxin Qin1

1Naval University of Engineering, 430032, Wuhan
2China91863 troops of the Chinese People's Liberation Army

*Corresponding author email: 21238747@qq.com

Abstract. For realizing the comprehensive monitoring of the ships and warships, the internet of things (i.e., IOT) technology is adopted by the local control system, which consists of the sensing layer, the transmission layer and the whole ship monitoring layer. First, state data is collected by various high-precision sensors of the sensing layer, and then transmitted to the entire ship monitoring layer via the entire ship transport layer based on Modbus TCP/IP design. The local control system is based on the STM32 MCU. It integrates functions such as signal acquisition, Ethernet, CAN bus communication, interactive display, and fault diagnosis. The effectiveness, practicability and flexibility of the on-site control system were verified by a ship propulsion experimental system. The on-site results can provide and verify big data technical support for different regions, regulatory agencies and equipment maintenance of the whole ship.

1. Introduction

As an important part of the comprehensive monitoring device of the cabin, the on-site control system is mainly used for unified monitoring and control of the operation information of the machine, electricity and liquid equipment distributed in the cabin [1,2]. The operation practice found that the cabin integrated monitoring device puts forward the following functional requirements for the on-site control system: (1) signal acquisition and control functions. (2) Ethernet and CAN bus communication functions. (3) operational display interactive software, through man-machine the interactive interface is operated. (4) monitors the running status of the device itself, and has fault diagnosis function. (5) has power supply redundancy, control redundancy, external communication interface redundancy function, and supports I/O channel redundancy function. The availability of these features greatly enhances the stability of the ship's system, better control performance and higher energy efficiency. During the investigation, it was learned that there is no such mature device or system on the market. Due to the complicated working conditions of the ship and the harsh environment, the possibility of failure is extremely great. Therefore, the health status and fault conditions of the ship's on-site operating system are timely grasped. It is of great significance for ship system monitoring and fault diagnosis.

In recent years, under the efforts of Internet network companies (such as Baidu, Alibaba, Tencent), big data analysis has become an important means for potential customers and consumer demand mining, Internet, artificial intelligence, and fault diagnosis. In ships, from ship power stations, ship power grids to ship electric propulsion, and various power loads and control systems, massive state data is generated every moment, so the dynamic quality of ship systems can be known in time with big data analysis. Predict the abnormal changes or operational failures that may occur on the ship [3]. In real-time power quality detection systems that perform real-time, dynamic and diverse grid dynamic parameters, it is inevitable to rely on high-speed industrial Ethernet and computers to conduct multi-dimensional analysis.
of power quality real-time data and historical storage data in the past, present and future. Based on this, considering the technical characteristics of the Internet of Things (i.e., IOT), the Internet of Things technology can be applied to the structural level design of the ship cabin integrated monitoring system, so that the monitoring system becomes a multi-layer structure monitoring platform to ensure Monitor the reliability, real-time and convenience of the work, and finally achieve the whole ship data sharing [4]. This paper proposes an overall structure of the on-site control method centred on the IOT technology, which is applied to the comprehensive monitoring of the cabin. It introduces its system composition method, functional use and design flow, and uses the ship propulsion experimental system as the monitoring object (object layer). Verify the feasibility and effectiveness of the power quality monitoring system.

2. Local Controller Network Architecture

The Local controllers are all modularized and divided into power modules (i.e., Power), main core processor modules (i.e., Main CPU), secondary core processor modules (i.e., Secondary CPU), digital input modules (i.e., DI), digital output modules (i.e., DI), analogue input modules (i.e., AI), analogue output modules (i.e., AO), main CAN modules (i.e., CAN1), secondary CAN modules (i.e., CAN2), Display modules, Backplane modules, etc., depending on the type of signals collected. The network architecture of the Local controller system is shown in Figure 1. The number is flexibly combined to meet most field acquisitions.

The Local controller system collects common input signals such as voltage and current [5]. For non-standard signals, it needs to be connected to the device after being converted into a standard signal through the conditioning circuit outside the device. For external devices that need to be controlled, the device only outputs control logic signals. The amplification or further processing of the signal is completed outside the device, thus ensuring the clear use of the device, uniform volume, and standardization.

![Network architecture diagram of the Local controller.](image)

Switches 1 and 2, including the display module, are adopted as peripherals of the on-site controller. A total of 11 acquisition slots are designed for the size of the equipment. Currently, 9 slots can be used, and the other two slots can be reserved. The function of each acquisition card of the Local controller is briefly described as follows:

(1) Two external independent output 24V DC power supplies. All modules are powered by the power bus, and the two power supplies are seamlessly switched. When one power module is damaged, other modules are not powered down.

(2) The display module receives and controls the data of the main processor module through the CAN interface, and the display module simultaneously receives the data of the two main processor modules.

(3) The sensor signal of the analogue output is accessed through the channel interface of the analogue input circuit board, and the data is sampled, A/D converted, etc., and transmitted to the CPU board through the backplane.

(4) Through the backplane, the CPU board will output 4-20mA analogue quantity, and output 4-20mA through the analogue output board.
(5) The digital output sensor signal is accessed through the channel interface of the digital input circuit board, and the data is optically separated and level-converted, and transmitted to the CPU circuit board via the backplane.

(6) Sensor CAN module, adapted to the special needs of CAN interface sensors.

(7) Point-to-point emergency control function module, adapted to the point-to-point emergency control requirements of the Local controller.

(8) Through the backplane, the digital quantity to be conditioned by the CPU board is outputted by the digital output board.

3. Design Details of the Local Controller Hardware

The hardware of the Local controller mainly collects different signals i.e., current signal, voltage signal and switching signal, respectively coming from the AI (Analog input) board and the DI (Digital input) board. At last, they are transmitted to the CPU board for processing. The CPU board transmits the processed current signals and switching signals to the AO (Analog output) board and the DO (Digital output) board output signals, and the CAN module and Information exchange between CPU modules. The IOT block diagram of each electrical board is illustrated in Figure 2.

Figure 2. Local controller hardware block diagram.

The function of each board of the field controller is briefly described as follows:

(1) The externally collected signal is transmitted to the core board through pre-processing, filtering processing, and amplitude conversion of the AI board, and the core board sends a feedback instruction to the AO board after receiving the signal of the AI board.

(2) The signal input by the external device is transmitted to the core board through the photoelectric isolation and shaping of the DI board, and after receiving the signal of the DI board, the core board sends a feedback instruction to the DO board.

4. Design Details of the Local Controller Software

Ship commanders, crew management and maintenance personnel, and other professionals can obtain power quality information of the ship's electric propulsion system, such as power parameter data, fault event records, and alarm information records, on the ship through the handheld terminal and the host computer. The crew of the unit operation, operation, management and maintenance provide real-time monitoring data, and provide the propulsion system status information for the ship commander who issued the navigation command, for the weapon operators, logistics support personnel, deck staff and other needs in real time during the war. Provide technique support from professionals, and they have access to ship status and emergency alert information.

The expression of the voltage static deviation $\delta U$ is:

$$\delta U$$
\[ \delta_U = \left( \frac{U - U_N}{U_N} \right) \times 100\% \quad (1) \]

where \( U \) is the measured voltage root mean square value; \( U_N = 220 \) V (single phase), which is the rated voltage root mean square value. According to the classification society’s standards, the voltage static deviation \( \delta_U \) is limited to: -10\% to +6\%.

The definition equation of the voltage dynamic deviation \( \delta_{Ud} \) is:
\[ \delta_{Ud} = \left( \frac{U - U_N}{U_N} \right) \times 100\% \quad (2) \]

According to the classification society’s standards, the voltage dynamic deviation \( \delta_{Ud} \) is limited to ±20\% (within 1.5 s).

The definition equation of the frequency static deviation \( \delta_f \) is:
\[ \delta_f = \left( \frac{f - f_N}{f_N} \right) \times 100\% \quad (3) \]

where \( f \) is the measured frequency; \( f_N = 50\)Hz, which is the rated frequency. According to the classification society, the frequency static deviation \( \delta_f \) is limited to ±5\%.

The definition equation of the voltage total harmonic distortion rate \( THD_U \) is:
\[ THD_U = \sqrt{\sum_{k=2}^{\infty} \left( \frac{U_k}{U_1} \right)^2} \quad (4) \]

where \( U_k \) is the root mean square value of the \( k \)th harmonic voltage component, where \( k = 2, 3, \ldots, \infty \); \( U_1 \) is the root mean square value of the fundamental voltage component. According to the classification society, the total harmonic distortion rate \( THD_U \) is limited to 5\%.

The definition equation of the current total harmonic distortion rate \( THD_I \) is:
\[ THD_I = \sqrt{\sum_{k=2}^{\infty} \left( \frac{I_k}{I_1} \right)^2} \quad (5) \]

where \( I_k \) is the root mean square value of the \( k \)th harmonic current component, where \( k = 2, 3, \ldots, \infty \); \( I_1 \) is the root mean square value of the fundamental current component.

The definition equation of the \( k \)th harmonic voltage content rate \( HRU_k \) is:
\[ HRU_k = \left( \frac{U_k}{U_1} \right) \times 100\% \quad (6) \]

The definition equation of the voltage negative sequence imbalance \( \varepsilon_{U-} \) is:
\[ \varepsilon_{U-} = \left( \frac{U^-}{U_+} \right) \times 100\% \quad (7) \]

where \( U_+ \) is the root mean square value of the positive sequence component; \( U_- \) is the root mean square value of the negative sequence component.

The definition equation of the voltage zero sequence imbalance \( \varepsilon_{U0} \) is:
\[ \varepsilon_{U0} = \left( \frac{U_0}{U_+} \right) \times 100\% \quad (8) \]
where $U_0$ is the zero-order component root mean square value.

The main flow chart is now shown by Figure 3. The main flow chart includes such key steps as Hardware initialization, Data initialization, mail loop starts and so on.

**Figure 3.** Main flow chart of the Local controller system centred on IOT.

Figure 4 illustrates the communication flow chart of the Local controller. The communication flow chart includes such key steps as refresh data area and logo, counter increment, set communication fault flag, and so on.

**Figure 4.** Communication flow chart of the Local controller system centred on IOT.

5. Engineering Verification and Operation Results

The designed controller will communicate the collected digital and analogue quantities as well as the output digital and analogue data through Ethernet. We use the controller as the server and the platform management centre as the client. The program needs to send the corresponding message from the client (displaying the current collected amount and the amount of control output), and the controller, is the server, will return the response message, wherein the response message displays the number required by the client according to the protocol. And analogue, can also display information about the controlled output.

The designed controller acts as the Modbus TCP Server (service) end, and the terminal device is the Modbus TCP Client (client) end; the rate is 10/100 Mbps adaptive; the upper computer access period is 100 mS; and the Modbus function codes are used: 0x03, 0x06, 0x10.
Due to the limited space, this paper only gives the engineering prototype setting interface diagram of the 1# unit parameter column (shown in Figure 5). Figure 5 shows the Display Tab of the 1# unit parameter column. It is responsible for displaying the operation, preparation and remote-control status of the 1# unit, and monitoring the status parameters such as the over-limit alarm of the inlet air environment temperature, the over-limit of the alarm outlet air environment temperature among the 1# unit cabinet.

![Figure 5. The window of unit 1 parameters of the Display Tab.](image)

6. Conclusions
The STM32 series is the main chip of the local control system. In the hardware aspect, the Ethernet circuit is used as the object, and a controller of dual redundant Ethernet communication is designed. First, the sensing layer measures the power quality data of the power propulsion system through high-precision sensors; then, the whole ship monitoring layer communicates through the entire ship transport layer, and obtains and analyses the power quality information anywhere through the upper computer software and hardware. And display; finally, the ship's electric propulsion experimental system is used as the physical layer to verify the feasibility and practicability of the monitoring system. Through the Internet, the control and data acquisition of the serial device can be extended to each terminal on the Internet, and the data acquisition and instrument control of the parameters required for the ship energy system can be conveniently performed, and the highly integrated ARM embedded processor is adopted. And the communication interface adopts redundant design, so that it can switch to the normal standby channel in time in the case of one channel failure, which increases the reliability, makes it system miniaturization, low cost, low power consumption, stable operation, etc. Features, with application reference value.

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