Abstract. The power system of the ship is closely related to the ship’s shipping, production and operation, navigation and communication, daily life and other subsystems, and has a very important impact on the operation of the ship. Due to the characteristics of the micro-grid of the ship and the use of a large number of power electronic equipment, the reliability of the power system of the ship is reduced, and the power quality of the power grid continues to decline. This paper studies the power parameter monitoring of the ship’s power grid, and designs a power parameter monitoring system for the ship’s power grid, which can monitor the power parameters of the ship’s power grid in real time. It is helpful to master the operation of the ship power system, and plays a positive role in improving the power quality of the ship power grid, and ensuring the safety and economic operation of the ship power system.

Keywords: Ship, Power Grid Parameter, Monitoring System, Detection

1. Introduction
In the history of ship development, the application of electrical energy has developed from scratch. At the beginning of the 20th century, merchant ships first used electrical energy. Initially, several kilowatts of DC generators were used to power lighting loads, but at that time electrical energy was an auxiliary energy source. However, with the development of large-scale automation of ships, in addition to powering conventional lighting loads, various accessories of ships, communication and navigation equipment, and electrical resistance of various alarm devices, ships can also use electrical energy. More and more ship operations require electricity [1]. In all-electric ships, the ship’s navigation also depends on electricity. The ship's power system is closely related to the shipping, production activities, navigation and communication, daily life and other subsystems.

2. Monitoring system and measurement of ship power grid parameters
2.1. Ship power grid system
The power system is an important part of modern ships. It can be divided into four parts: power plant, power distribution equipment, transmission network and load. For emergency generators, ACB1,
ACB2, ACB3, ACB4 are air circuit breakers, MCB is a molded circuit breaker, and ABTS is a busbar contactor.

Figure 1. Single-line schematic diagram of ship power system

Ship power station is the source of electric energy for the entire ship, currently mainly composed of diesel generators and batteries. Power distribution equipment is mainly used to control, protect, monitor and distribute the electricity generated by ship power plants. It can be divided into main switchboard, emergency switchboard, regional switchboard, charging and discharging board, coastal power box, etc. The on-board power grid is the general term for the feeder system, which is composed of cables and wires and supplies power to the cables. It has the function of sending electrical energy to the ship and all the electrical equipment on the ship.

2.2. Design of the monitoring system for ship power grid parameters

For ground power systems, smart grids have always been the focus of attention and research of domestic and foreign researchers. The smart grid applies advanced sensing and measurement technology, information and communication technology, computer technology, and automatic control technology to the transmission and distribution process to form a new type of power grid and improve the observability of the power grid [2]. It can not only improve operational safety, reliability and stability, reduce grid operation and maintenance costs, but also improve grid power quality, reduce transmission and distribution losses, and increase grid asset utilization.

2.3. Ship power grid parameters

2.3.1. Power parameters of onshore power grid. People have first started to use large ground power grids before. Regarding the power quality of the power grid, due to the initial power shortage in our country, people are worried about how to provide enough power, but they pay less attention to power parameters. They often only evaluate the two parameters of voltage and frequency. However, the gradual easing of power tensions as well as the use of a large number of electrical appliances is reducing the quality of the power grid and affecting the safe and efficient operation of the power grid.

2.3.2. Power parameters of ship power grid. Marine and terrestrial grids have similar problems. Due to the characteristics of ship micro-grids, the power quality problems in the power grid are more serious, and there are few power quality indicators in the ship power grid and the evaluation system is
not perfect. China's "Rules for the Classification of Steel Ships" only stipulate the stability and partial transients of voltage and frequency.

3. Measurement method of ship power grid parameters

3.1. Sampling method of ship power grid parameters

The parameters depend on the sampling method. Power parameter measurement can be divided into two categories: DC sampling and AC sampling. In DC sampling, the transmitter rectifies the grid signal to obtain the corresponding DC amount \([3]\). Then, the AD device samples the DC quantity to obtain the corresponding power parameters. The advantage of this method is that the sampling period is short and the algorithm is simple. However, since only the correction value is sampled, the amount of information retrieved is small and cannot reflect the instantaneous information being measured. In addition, the parameters obtained are single, and the accuracy of the parameters is directly determined by the accuracy and stability of the transmitter.

3.2. Measurement methods of conventional power grid parameters of ship power grid

(1) Measuring method of the effective value of voltage and current

If an alternating current and another direct current pass through the same resistor to generate the same heat at the same time, the voltage and current values of the direct current are the effective values of the alternating current respectively. The effective value is also called the root mean square value. The formula for the continuous signal used to calculate the effective voltage value is as follows:

\[
U = \sqrt{\frac{1}{T} \int_0^T u^2(t) dt}
\]  

(2.1)

When the continuous signal \(u(t)\) is sampled discretely, that is, \(N\) data points are sampled at equal intervals in a period \(T\), the above-mentioned analog integral expression can be converted to the discrete summation expression shown in equation 2.2, where \(T\) is the sampling interval and its value is \(/TTN\), and \(u[n]\) is the \(n\)th sampled value of the analog voltage signal.

\[
U = \sqrt{\frac{1}{T} \sum_0^N u^2[n\Delta T]} = \sqrt{\frac{1}{N} \sum_0^N u^2[n]}
\]  

(2.2)

3.3. Measurement method of harmonic parameters of ship power grid

The \(h\)th harmonic content and total harmonic distortion (THD) are usually used for measurement to characterize the degree of distortion of the grid voltage or current waveform. The calculation formulas for harmonic voltage content and harmonic current content are as follows.

\[
HRU_h = \frac{U_h}{U_i}
\]

\[
HRI_h = \frac{I_h}{I_i}
\]  

(3)

The voltage total harmonic distortion rate THDU and current total harmonic distortion rate THDI are calculated as:
In this formula, $U_h$ is the effective value of the hth harmonic voltage, $U_1$ is the effective value of the fundamental voltage, $I_h$ is the effective value of the hth harmonic current, $I_1$ is the effective value of the fundamental current, and $M$ is the effective value of the harmonic to be considered. Whether it is harmonic content or total harmonic distortion, it is important to obtain the amplitude of each harmonic [4].

4. Design of monitoring system for ship power grid parameters

4.1. Overall design plan
The traditional power parameter monitoring terminal is usually designed with a single processor, such as ARM or DSP. When completing tasks such as parameter calculation, human-computer interaction, and communication, peripheral circuits such as AD and memory are also required. If the sampling rate is low, this solution can basically meet the requirements. When the sampling rate of the target monitoring terminal is increased to 12.8K times/sec, it will take up frequent AD sampling to trigger interrupts and conversions in order to complete the interrupts. If the CPU time is too long, the data sampling process will occupy software resources [5,6]. At the same time, frequent interruptions destroy the original execution process of the program, reduce the efficiency of program execution, and deteriorate the system in real time, making it difficult to meet the needs of real-time monitoring.

4.2. Selection of key components

4.2.1. AD selection. Since the ship’s power systems usually use three-phase three-wire systems, it is necessary to collect at least 6 channels of waveform data. Traditionally, multi-channel signal acquisition is usually done by sharing the analog switch of the AD converter, and each signal is sampled and converted over time. If the data acquisition of each channel is not synchronized, this will not only complicate the circuit, but also cause errors. Therefore, choosing an AD device with more than 6 channels and synchronous sampling function can be considered to eliminate the problem of inaccurate calculation results caused by asynchronous data collection for each channel in the hardware. There are many AD chip models that meet these characteristics, but TI is the only chip with ADS7864, ADS8634, ADS8556 and other models that meet the requirements, so this model must be further determined in conjunction with other requirements.

4.2.2. FPGA selection. Field programmable gate array (FPGA) is a programmable logic device that allows designers to use traditional schematic input methods or VHDL/Verilog hardware description language to provide specific functions on an empty FPGA chip. The circuit module is a fully functional digital system. FPGA can obtain various hardware structures and hardware functions by loading various configuration files, thus becoming an IC that can change its circuit functions at any time. Because of this reconfigurable hardware function, FPGAs are often referred to as "liquid hardware."
4.3. FPGA programming

Figure 2. Functional block diagram of FPGA circuit

As a monitoring terminal co-processor, FPGA is mainly responsible for tasks such as power grid signal sampling control and FFT operation. According to the needs of the monitoring terminal, the FPGA part of the circuit should be a minimal system, including a crystal oscillator circuit, a configuration memory circuit, a program download interface, and a power supply shared with ARM. This section describes the circuit design of the FPGA chip itself. Figure 2 shows the functional block diagram of the FPGA circuit and the interfaces used by the FPGA chip. AD chip sampling control is an important function that FPGA must perform. According to the ADS7864 operating sequence shown in the figure, the AD sampling controller completed the task of collecting 6-channel signal data synchronously from the ship's power grid. The working process is as follows: the PLL_Out signal output by the phase-locked frequency multiplication circuit is processed by FPGA (square wave signal is converted into pulse signal) and output through the ADHOLD pin to control the start of the AD sampling process. The signal reflecting the conversion state of the AD chip is input to the FPGA through the ADBUSY pin. After the data conversion is completed, a low-level pulse is output from the ADRD pin to read the result data and output AD_DB [7]. It is input from the terminal to the FPGA. Since it is an 8-bit data interface, the conversion result of each channel must be read twice.

5. Testing of the monitoring system of ship power grid parameters

5.1. Formation of the test system
In order to verify and test the performance of the power parameter monitoring system of the ship's power grid, it is first necessary to build a complete test system based on the monitoring terminal. Figure 3 is the physical diagram of the monitoring terminal developed in this article. The test system consists of a computer, a USB CAN adapter and six monitoring terminals. The CAN network uses ordinary twisted pair as the transmission medium, and the communication baud rate is set to 500 kbps.
5.2. Comparison of monitoring terminal measurement results
We have conducted some comparative tests to verify the accuracy of the parameter measurement of the monitoring terminal, but due to laboratory conditions, the effective values of voltage, current, harmonics, etc. have been accepted. This test method uses the developed monitoring terminal and standard instrument to detect the power parameters of the same electrical load, records the measurement data every 3 minutes, and then compares the measurement results. The electric load used here is an electric kettle. In the laboratory, its rated working voltage is 20V and the rated power is 1800W. As the test standard table for reference and comparison, the VC97 multimeter and FLUKE43B power quality analyzer with an accuracy of 33/4 digits were selected, and the voltage measurement was performed. The error is very small, with a relative error of less than 0.1%. But the stability of voltage measurement needs to be further improved. The current RMS measurement error is also relatively small, with a relative error of about 1%.

5.3. Error analysis of monitoring terminal measurement
Parameter measurement accuracy is an important indicator of the power parameter monitoring system of the ship's power grid. Due to laboratory conditions, it is temporarily impossible to use sophisticated equipment or device to conduct a comprehensive test on the monitoring terminal, but the existing measurement data indicates that the system has measurement errors.

In order to reduce and eliminate errors, the system must perform error analysis. The error of measuring instrument can be divided into systematic error and random error. Random errors can make the measurement unstable. Therefore, software filtering can reduce or eliminate the method of averaging multiple measurements. In the case of system errors, the monitoring terminal mainly has the function of hardware processing circuit errors and software algorithm errors.

6. Conclusion
The ship’s network power parameter monitoring system continuously receives a large number of uploaded power parameters from various monitoring terminals. These power parameters are not only directly used to characterize the power quality of the ship's transmission network, but must continue to be developed through data mining and data integration technologies. It provides more analysis and application-level tasks to enable higher-level applications, such as power flow monitoring, load forecasting, fault diagnosis, energy management, and grid dispatching. Although a prototype has been developed in this article, the monitoring system has not yet been deployed in the actual ship’s power grid. Due to the harsh working environment of ships and the coexistence of various electromagnetic interferences, various anti-jamming measures have been taken in the design of hardware and software, but it is necessary to actually test the system and its anti-interference ability.
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