An Improved maintenance method for marine electrical equipment based on the Internet of Things

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Abstract. Due to the influence of high temperature and high humidity, the failure rate of marine electrical equipment is higher than that in other situations. The stability of the electrical equipment of ships is of vital importance to the safety of navigation. Traditional electrical maintenance methods have the problem of lagging in response to equipment fault detection and feedback, which is caused by the signal transmission mode. This article applies the Internet of Things technology to the maintenance of marine electrical equipment, which can improve the performance of the maintenance method. Firstly, the fault detect program architecture is adjusted and optimized. The fault sensing modules are placed in the electrical equipment. The traditional electrical signal transmission mode is replaced by the network transmission mode. Then, the fault signal anti-jamming algorithm is used to optimize the compensation calculation of the alarm signal of the electrical equipment fault point to achieve the effect of enhancing the signal sensitivity; finally, the fault detection sensitivity of the proposed method is tested through experiments, and the data shows that the design method is better than the traditional maintenance method.

Keywords: Internet of things; Electrical equipment; ship; maintenance method.

1. Introduction
The degree of automation of ships is getting higher and higher, and the functionality of ships continues to expand and improve. Electrical equipment has become a standard configuration of ship design. As more and more electrical equipment are configured on ships, the maintenance and overhaul of electrical equipment becomes more and more difficult. Affected by the complexity of electrical equipment [1], conventional maintenance methods cannot meet the needs of maintenance and repair in terms of maintenance efficiency. This is mainly reflected in the single detection method of electrical equipment, and it is impossible to monitor the operating status of electrical equipment in real time. High-speed feedback of data, And the recognition sensitivity of electrical equipment fault signals and the integrity processing of feedback signals.
2. Realization of optimization of ship electrical equipment maintenance structure based on Internet of Things technology

2.1. Establishment of communication structure of electrical equipment fault detection network

According to the characteristics of ship electrical equipment maintenance, combined with the Internet of Things technology, the ship electrical equipment fault status information data is analyzed and classified by network intelligence, the data structure network system is classified, and the electrical status induction feedback detection mode using the network as the communication medium is adopted. The detailed electrical equipment fault detection network communication structure is shown in Figure 1.

**Figure 1.** Network communication structure of electrical equipment fault detection

The designed electrical equipment fault detection communication network based on the Internet of Things technology includes three functional structure layers, namely the detection data collection layer, the communication layer and the judgment layer.

2.1.1. The judgment layer is the core functional layer in the maintenance design. It mainly analyzes and judges the real-time status of the collected ship electrical equipment data through network big data analysis. In order to ensure the real-time data analysis, the functional structure layer The network protocol uses the IPV6 standard to adapt to the processing of complex electrical network data.

2.1.2. The optimized design of the transmission layer mainly improves the transmission mode and transmission rate of the network. Targeted optimization on the network topology has increased the data interaction capability of the single-layer link, improved the anti-interference of the data node, and further reduced the probability of congestion in the communication network link during the communication process. At the same time, different from the traditional communication layer, the optimized communication layer has the ability to evaluate and classify the status of electrical equipment. It is convenient to determine the type and location of electrical equipment faults quickly at the level, and provide maintenance plans. For example, for the evaluation of the power supply and transformation system in marine electrical equipment, the detailed evaluation parameters are shown in Table 1.
Table 1. Evaluation scope of ship Power supply Transformer Transmission

| Name of equipment | Code of equipment | Monitoring and Evaluation items |
|-------------------|------------------|---------------------------------|
| Body              | Q₁               | Winding high-voltage parameters, winding low-voltage parameters, insulation protection, clapboard, temperature sensor. |
| Envelope          | Q₂               | Winding medium voltage parameters. Winding dynamic voltage parameters, gas relay controller |
| Cooling system    | Q₃               | Radiator, heat pipe, control box |
| Power controller  | Q₄               | On-load tap-changer, no-load tap-changer |

2.1.3. The detection data collection layer is mainly used for the detection of the status of the ship's electrical equipment and the real-time transmission of status data. Among them, it mainly includes: oil and gas detection sensors, power monitoring sensors, conventional detectors for live equipment, GIS modules, mobile data collection terminals, central equipment data collection induction modules, electrical equipment line monitoring modules, all modules are wireless. The network signal is connected to the network to realize real-time data communication between local and remote. On the basis of network communication, through the use of Internet of Things technology, the detection of oil and gas production and the detection of electrical sensitive areas, infrared transmission and radio frequency transmission technologies are used. Further improve the reliability of the inspection and maintenance of marine electrical equipment.

2.2. Sensitivity Compensation Calculation of Electrical Fault Detection Signal Based on Internet of Things Technology

In the traditional process, there will be the problem of signal loss. In order to ensure the stability of the network signal, the wireless transmission signal is compensated and optimized. The specific optimization steps are as follows:

Suppose the sending signal of the ship electrical state data acquisition module is \( D(i) \). The fault-tolerant parameter of the signal is \( D_1(i) \). Missing signal parameters can be determined and obtained by signal authentication. The calculation formula for the determination of lost signal is:

\[
\begin{align*}
D_1(i) & \in D(i) \\
D_1(i) & \in \{yc_1, yc_2\} \geq l
\end{align*}
\]

In the formula \( c_1, c_2 \) represent the maximum and minimum peak coefficients of the signal; \( y \) represents the intensity change of the signal; \( l \) represents the maximum threshold of the signal gradient.

After the determination of the missing state feedback signal is completed, the signal is compensated and imported to restore the missing signal that is lost due to the interference of data fragments [2], so as to improve the transmission rate and transmission stability of the detection signal feedback. The compensation calculation of the seeking truth signal consists of two aspects: the calculation of the missing amount of the compensation signal and the compensation import calculation of the missing amount.

2.2.1. The amount of missing signal in the network link can be calculated by a linear relationship function:

\[
g(D_i(i)) = q \cdot \frac{t \cdot \sqrt{b^2 + x^2}}{j}
\]

In the formula \( q \) represents the anti-interference rate of signal transmission; \( t \) represents the dynamic amount of signal fluctuation; \( b \) represents the intensity of fragment interference; \( x \) represents the total amount of missing signal fragments; \( j \) represents the compensation tolerance value.

Set the \( b \) value in formula (1) to 0, and perform unary linear regression calculation on it:
The missing amount $s$ of the missing signal can be obtained by formula (3), and the missing amount $s$ is imported into the signal compensation model to complete the compensation calculation for the missing signal.

$$s = \begin{bmatrix} [ g_2 - g_1 ] \\ [ g_1 - g_2 ] \\ \Lambda \\ [ g_{i-1} - g_i ] \end{bmatrix} \in (0,1)$$  

The missing amount $s$ of the missing signal can be obtained by formula (3), and the missing amount $s$ is imported into the signal compensation model to complete the compensation calculation for the missing signal.

2.2.2. After importing the missing quantity $s$ into the compensation model [3], the normalization calculation of the vector parameters is carried out on it, so that different parameters can be arranged in different parameter value ranges, and the compensation effect of signal learning [4] is realized. The normalized function calculation equation is:

$$s' = \left( \frac{z(i - i_{\min})}{p} \right) - \left( \frac{z(i_{\max} - i_{\min})}{2p} \right)$$  

$s'$ represents the total amount of normalized calculation; $z$ represents the dynamic value of signal normalized calculation; $i_{\max}$, $i_{\min}$ represent the maximum and minimum values of the loaded coefficient and the derived coefficient respectively; $p$ represents the dynamic variance of the compensation coefficient.

Bring the above calculation amount into the compensation model, make it meet the restriction conditions in formula (5), and import it into the model compensation layer based on the missing amount $s$.

$$A = \sum_{s=1}^{1} SM - m \cdot f$$  

$A$ represents the compensation target amount; $S$ and $M$ represent the update function amount of the missing signal structure layer and the compensation structure layer; $m$ represents the weight of the initial variance; $f$ represents the set constant. Calculate at the missing signal structure layer, and solve:

$$T = \mu \left[ e \cdot s' \right]$$  

$\mu$ Represents the compensation iteration amount; $e$ represents the weight coefficient. Calculate the compensation layer solution:

$$T' = \mu \left[ e \cdot T \right]$$  

The output compensation amount of the compensation structure layer is:

$$\Phi = \Psi - T'$$  

$\Psi$ represents preset output; $T'$ Represents the maximum or minimum value of the compensation signal.

3. Simulation data import verification

The simulation test program randomly selects 300 groups of ship electrical equipment status signals and divides them into 10 groups. Each group is composed of normal signals and fault signals. Normal and fault signals are random. The detailed parameters and results of the experiment are shown in Table 2 and 3.

Table 2. Experimental Design parameters

| Standard error range | Duration of test | time interval of test | Data processing |
|----------------------|------------------|-----------------------|-----------------|
| 0.5%−1%              | 120min           | 30s                   | mean            |
### Table 3. Sensitivity test results of maintenance methods

| Group No. | Number of normal signals | Number of fault signals | Failure detection rate before optimization | Failure detection rate after optimization |
|-----------|--------------------------|-------------------------|-------------------------------------------|------------------------------------------|
| 1         | 1                        | 2                       | 87%                                       | 98.7%                                    |
| 2         | 1                        | 2                       | 86.3%                                     | 98.7%                                    |
| 3         | 2                        | 1                       | 84%                                       | 99.7%                                    |
| 4         | 2                        | 1                       | 84%                                       | 99.4%                                    |
| 5         | 1                        | 2                       | 87%                                       | 98.7%                                    |
| 6         | 0                        | 3                       | 89.2%                                     | 99%                                      |
| 7         | 0                        | 3                       | 89%                                       | 99%                                      |
| 8         | 2                        | 1                       | 83.1%                                     | 98.4%                                    |
| 9         | 1                        | 2                       | 85.8%                                     | 98.5%                                    |
| 10        | 0                        | 3                       | 88.6%                                     | 99.3%                                    |

According to the detection rate is an important condition for determining the sensitivity of the maintenance method, the data in Table 2 before and after the optimization of the maintenance method are compared, and the following conclusions are drawn:

The optimized design of the maintenance method for ship electrical equipment based on the Internet of Things technology is proposed. In the fault detection and identification of electrical equipment, the sensitivity is significantly higher than the maintenance method before optimization, and combined with multiple sets of data parameter analysis, the optimized maintenance can be determined. The method has good stability in fault detection of marine electrical equipment, and meets the design requirements for daily use.

### 4. Conclusion

Aiming at the problem of poor detection and identification sensitivity of fault signals in the maintenance of marine electrical equipment, combined with the Internet of Things technology, an optimization analysis of the maintenance method of ship electrical equipment based on the Internet of Things technology is proposed. In view of the current structural characteristics of the fault detection network for ship electrical equipment maintenance, through the use of Internet of Things technology, the electrical equipment detection network structure was redesigned, the network structure was optimized, the Internet of Things detection sensor module was added, and the network detection signal was carried out. Compensation optimization calculation, complete the description of the whole process of design method optimization. The fault detection sensitivity of the maintenance method before and after optimization is verified through experiments, which proves that the design optimization method has the characteristics of high sensitivity and stable detection state. It provides a new feasible plan for the overhaul and maintenance of marine electrical equipment.

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