Design of power decommissioning material management system based on RFID technology

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Abstract. Due to the existence of many interference factors, the recognition rate of the existing power decommissioning material management system is low when reading material labels, so a power decommissioning material management system based on RFID technology is designed. In the hardware part, RF transmitting circuit and receiving circuit are designed to collect and process the specific information of decommissioning material tags in real time. In the software part, the main performance requirements of the system are determined according to the business process of power decommissioning materials management. Radio frequency identification technology is used to identify the communication tag of decommissioning electrical materials, and the system function module is designed to realize the data transmission between the system function module and the non-contact communication tag. The experimental results show that the label recognition rate of the system designed in this paper is 10.08% and 6.17% higher than that of the management system based on one-dimensional bar code recognition technology and two-dimensional bar code recognition technology, respectively. The system has good ability of reading and identifying the labels of decommissioning materials, which is conducive to improving the information management level of power enterprise.

1. Introduction
With the continuous expansion of the scale of power grid construction, more and more power grid materials are withdrawn from operation and idle materials in the warehouse every year, which causes the waste of power grid material resources to a certain extent and reduces the use efficiency of assets [1]. The decommissioning of electric power materials refers to that the physical assets in production and operation are out of operation or use due to their own performance, technology, economy and other reasons. After the decommissioned equipment is technically identified, the physical assets storage department completes the transfer and storage of dismantled equipment and reused equipment. At the same time, the physical assets storage department initiated and completed the reuse, scrap approval and financial accounting process in the power decommissioning materials management system [2]. The main advantages of RFID technology are non-contact, good permeability, strong adaptability to harsh environment, and rapid identification of label information [3]. Based on RFID technology, it can achieve the goal of accurate and rapid transmission of material information, and dynamic and remote automatic identification of decommissioning materials. In this paper, after the full research and analysis of RFID technology, storage management system and storage management requirements of power materials, the management system of power decommissioning materials is designed, and the RFID technology is introduced to identify, track and record the power decommissioning materials. Therefore, it can realize the real-time management of decommissioning materials, reduce the error rate of material records, and improve the efficiency of decommissioning materials management of power enterprises.
2. Hardware design of power decommissioning material management system

RFID reader is the core part of the acquisition device based on RFID technology. The design of this paper is the transceiver circuit of multi band RFID reader. Firstly the transmitting circuit modulates the command information to be transmitted to the local oscillator signal, and after amplification by the amplifier, it is transmitted by the antenna in the form of carrier [4]. Secondly the receiving circuit receives the backscattered signal of the tag through the antenna, demodulates it with the local oscillator signal after low noise amplifier, and generates the baseband signal. Finally which is analyzed by the computer processing system. The following is a detailed description of the transceiver circuit of RFID reader.

2.1. Design of RF transmitting circuit

The transmitting circuit of RFID reader adopts direct up conversion technology, and the main chip is ADL5385 quadrature modulation chip of ADI company. ADL5385 quadrature modulation chip is powered by 4.75V to 5.5V voltage, and its working frequency range is 30MHz to 2.2GHz. When the 350MHz signal is output, the sideband suppression is a 50dBc, which can modulate the wireless communication in the UHF frequency band, and has very good phase accuracy and amplitude balance, meeting the requirements of the transmission frequency band of this design [5]. The block diagram of ADL5385 is shown in Figure 1.

![Figure 1 Main chip structure block diagram](image)

When there are two pairs of baseband differential signals IBBP, IBBN and QBBP, QBBN and a pair of orthogonal local oscillator signals LOIP and LOIN input into the chip, the internal frequency mixing will be carried out, and the mixed signal will be output through an amplifier which can drive a 50Ω load. Because there is a frequency division circuit inside the chip, when the external LO signal LOIP and LOIN are input, the frequency division will occur.

2.2. Design of RF receiving circuit

The receiving circuit of RFID reader adopts orthogonal down conversion technology, and the main chip is ADL5380 quadrature demodulation chip of ADI company. ADL5380 quadrature demodulation chip uses 5V single power supply, which can demodulate the input signal from 400MHz to 6GHz, and the output baseband signal impedance is 50Ω after demodulation. When the chip works at 900MHz frequency, the phase accuracy is about 0.2°, the amplitude balance is about 0.07dB, the maximum input power is up to 11.6dBm, the noise figure is 10.9dB, and the third-order intermodulation cut-off point is 29.7dBm. When the RF signal is mixed with the LO signal, the output signal frequency is 10MHz, 856MHz or 1840MHz. By adding a low-pass filter circuit at the output end, only the 10MHz signal is filtered out. The schematic diagram of the receiving circuit is shown in Figure 2.
After the baseband signal is output, it enters the following digital attenuator and low noise amplifier circuit to complete the control of baseband signal power \[^9\]. In the circuit design, we need to pay attention to pull the enable pin ENBL of ADL5380 to low level, so that the chip can work normally.

3. Software design of power decommissioning material management system

3.1. Identification of communication tags of decommissioning electric power materials based on RFID technology

The RFID technology is used to identify the communication tags of decommissioning materials. The electronic communication tag carries the information of the identified items attached to the surface of the items. The number of tags sent at the same time is the same. The average packet switching volume is consistent with the average value over a period of time. The average packet switching capacity is calculated as follows:

\[
J = \frac{\sum_{i} \alpha_i}{\beta_i} \gamma_i \tag{1}
\]

In formula (1), \(J\) represents the average packet switching capacity; \(s\) is the number of tags; \(\alpha_i\) represents the time when the label transmits a packet; \(\beta_i\) is the observation time; \(\gamma_i\) indicates the number of packets sent by the tag during the observation time. When the throughput is 1, packets can be considered to be transmitted without conflict during transmission. In other cases, there is no message sent or the transmission data is not read successfully due to conflict. The average throughput of the transmission channel can be obtained from the average packet switching capacity. The calculation formula is as follows:

\[
H = Je^{(-J)} \tag{2}
\]

In formula (2), \(H\) represents the average throughput of the transmission channel; \(e\) is the natural constant. For a small amount of packet switching, the transmission channel is not utilized most of the time. The transmission of data packets only starts in the synchronized time slot, and the time interval of collision is further shortened. In this case, the slot throughput is calculated as follows:

\[
T = Je^{(-J)} \tag{3}
\]

In formula (3), \(T\) represents the slot throughput. When the average packet exchange is 1, the slot throughput reaches the maximum. Wait for the tag to answer when the reader sends the read command. When multiple tags answer, conflicts occur, and the conflict labels enter the waiting state, and the data is sent by selecting the slot again in the next frame. The reader repeats the above process continuously until no label information is received in a frame, all tags are considered to be identified.
3.2. Design system function module

According to the demand analysis, the system can be divided into five functional modules: storage management, task management, and system management. (1) Warehousing management. This module mainly completes the whole process of decommissioning materials storage, including material notice, receiving, warehousing task, shelf management, etc. Material notice is the most important voucher in the process of receiving materials. (2) Warehouse out management. This module completes all the processes of ex warehouse of decommissioning materials, including unloading operation, picking operation, picking list, ex warehouse task, and so on. Delivery notices need to be merged according to specific rules to generate waves, which can reduce the number of picking. Picking also needs to be carried out according to rules, such as first in first out rule, batch rule, full board/full container/scattered picking rule. (3) Task management. The module is not only convenient for warehouse management personnel to carry out business operations, but also responsible for the supervision of job tasks. At the same time, the task status will be divided into waiting to process tasks, completing tasks, waiting tasks, ongoing automation tasks, etc. In the design of this module, we need to use the similarity index of task state to execute the task. The calculation formula of task state similarity is as follows:

\[ d(a_1, a_2) = \frac{g(a_1) + g(a_2)}{|g(a_1) - g(a_2)| + 1} \]  

(4)

In formula (4), \(a_1, a_2\) represent two task states; \(d(a_1, a_2)\) represents the similarity of task states; \(g(a_1), g(a_2)\) represent the execution standard level of two task states. Usually, task management and automation equipment job quality correspond to each other, such as loading task, inventory task, unloading task, etc. (5) System management. System management in the system, the main function is to provide maintenance for basic data, basic data are material master data, warehouse master data management, reader configuration, customer basic data maintenance. For the creation of user roles and the allocation of permissions, the data of different levels of user access permissions will be limited.

4. Experimental test

4.1. Experimental preparation

In this paper, based on radio frequency identification technology design power decommissioning materials management system, the following system testing. In the software testing of power material management system, the data integrity constraints of power material management system in the basic data input and modification are mainly considered. The data integrity constraints and data standardization requirements of software testing in software engineering are mainly followed, which meet the basic requirements of software testing and functional use case operation. At the same time, the account setting, network access security and system security requirements of the system are considered in the test of the power decommissioning material management system. According to the requirements of software and hardware environment for the development of power material management system, the test environment of power decommissioning material management system is Microsoft Win10 operating system, the test server is Apache Tomcat server, and the test database is Microsoft SQL Server 2010. The hardware environment of the system is a personal computer with 8GB RAM, Intel dual core CPU and 2.2GHz main frequency. The dynamic test method is used to test the operation of the power decommissioning material management system, and the performance test results are shown in Table 1.
Table 1  System performance test results

| Number of concurrent users | Concurrent response time (s) | CPU utilization rate (%) |
|----------------------------|------------------------------|--------------------------|
| 10                         | 0.10                         | 1.1                      |
| 25                         | 0.12                         | 1.6                      |
| 50                         | 0.21                         | 2.9                      |
| 100                        | 0.42                         | 5.8                      |
| 200                        | 0.63                         | 11.6                     |
| 300                        | 0.92                         | 13.8                     |
| 400                        | 1.09                         | 16.4                     |
| 500                        | 2.46                         | 22.5                     |

According to the system performance test results in Table 1, the concurrent response time and CPU occupancy rate of the system meet the design requirements, and it has certain carrying capacity under specific experimental conditions, which indicates that the system has good stability and can ensure the fluency of various functions of the system.

4.2. Experimental result

On the basis of the above system performance test, this paper further analyzes the advantages of the electrical decommissioning material management system in material label identification. Select the power decommissioning material management system based on one-dimensional barcode identification technology and two-dimensional barcode identification technology as the experimental control group, and compare with the system based on RFID technology in this paper. In this paper, the label recognition rate is used to measure the reading effect of the system on the labels of decommissioning materials. The calculation formula of tag recognition rate is as follows:

\[ p = \frac{m}{u} \times 100\% \]  

In formula (5), \( p \) represents the identification rate of the label of the decommissioned materials; \( m \) is the number of tags successfully identified; \( u \) represents the total number of tags to be identified. The experimental results are shown in Table 2.

Table 2  Experimental results

| Serial number | Label recognition rate (%) |
|---------------|----------------------------|
|               | Management system of decommissioning materials based on RFID technology | Management system of power decommissioning materials based on one-dimensional barcode recognition technology | Management system of power decommissioning materials based on two-dimensional code recognition technology |
|---------------|-------------------------------------------------|-------------------------------------------------|-------------------------------------------------|
| 1             | 96.24                                           | 88.22                                           | 92.60                                           |
| 2             | 97.45                                           | 87.54                                           | 91.34                                           |
| 3             | 98.86                                           | 88.61                                           | 92.57                                           |
| 4             | 96.58                                           | 86.33                                           | 91.81                                           |
| 5             | 98.62                                           | 88.05                                           | 91.22                                           |
| 6             | 97.03                                           | 87.16                                           | 90.18                                           |
| 7             | 96.28                                           | 88.8                                            | 91.46                                           |
| 8             | 98.57                                           | 86.67                                           | 91.72                                           |
| 9             | 98.81                                           | 87.82                                           | 90.93                                           |
| 10            | 98.39                                           | 86.75                                           | 91.24                                           |

According to the experimental test results in Table 2, the tag recognition rate of the power decommissioning material management system based on RFID technology is 97.68%, the tag recognition rate of the power decommissioning material management system based on one-dimensional
barcode recognition technology is 87.60%, and the tag recognition rate of the power decommissioning material management system based on two-dimensional code recognition technology is 91.51%. According to the above results, the tag recognition rate of the system designed in this paper is 10.08% and 6.17% higher than that of the existing two management systems, respectively. Therefore, it has a good ability to read and identify the tags of decommissioning materials, which is helpful for power enterprises to manage and dispatch decommissioning materials conveniently and efficiently, and improve the information management level of power enterprises.

5. Conclusion
In this paper, the research and development of the system is mainly aimed at the management of the information related to the power decommissioning materials. The system functions provide many convenience for the management personnel of the power decommissioning materials, but there are also some shortcomings for the follow-up research and development. The main functions of the system are to manage the storage and delivery of decommissioning materials and related information. It can also be combined with the current popular artificial intelligence algorithm to realize the intelligent management and control of material scheduling and distribution. Specific data mining algorithm can be used to predict the demand of various decommissioning materials in the future. Based on the prediction results, the inventory of various materials can be sorted and scheduled in advance, so as to improve the forward-looking of material scheduling, which is conducive to the reuse efficiency of power decommissioning materials.

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