Research on the full life cycle management system of smart electric energy meter

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Abstract: At present, China's smart electric energy meter life management is started from the procurement and acceptance. The related monitoring and management of the manufacturing sector has not yet been carried out. This article applies RFID technology and network cloud platform to full life cycle management system of smart electric energy meters, builds this full life cycle management system including design and manufacturing, process control, measurement and calibration testing, storage management, user acceptance, site operation, maintenance scrap and other aspects. Exploring smart electric energy meters on-line and off-line communication by the application of active RFID communication functions, and the actual functional application such as local data exchange and instrument calibration. This system provides technical supports on power demand side management and the improvement of smart electric energy meter reliability evaluation system.

1. Introduction

As an advanced decision-making method and a management idea, Life Cycle Asset Management (hereinafter referred to as “LCAM”) can make assets optimal in security, efficiency and costs through an overall management of systematic plans & designs, purchasing & examinations, operations & maintenance, and scraps & cleanings, provided that utilization demands are satisfied and assets are operated in a safe, reliable manner.

From the second half of 2009 to the first half of 2015, State Grid Corporation of China invited bids of smart electric meters for 24 times, which made the bidding number of smart electric meters over 330 million. Due to the dispersion and complexity of electric meter assets, the asset management has been an important section of power grid enterprise management. The asset management of electric meters involves the routine maintenance & management of the operation status of fixed assets, the management of the storage and disperse statuses of fixed assets, and the accuracy and reliability of measurements[2, 3].

The Life Cycle Management of electric meters in the State Grid basically begins from the bidding and purchasing phases, while the relevant monitoring management fails to be carried out in the manufacturing section. The LCAM, which is established from apparatus designs, key component purchasing, manufacturing processes to delivery inspections, exerts a practical influence on the asset management of power grid enterprises and provides technological data for the power demand side management and for the improvement of the reliability evaluation system of smart electric energy meters.
This paper applies the Radio Frequency Identification (hereinafter referred to as RFID) technology\cite{4} and the Web-based cloud serving platform\cite{5} into the LCAM system of smart electric energy meters, aiming to establish a more improved management system. This LCAM system involves RFID designs of smart electric energy meters, an overall management of production & manufacturing procedures, automatic calibration equipment, a storage management system\cite{6}, a local data collection system and a cloud platform management system. This LCAM system will efficiently increase the automation of electric meter asset management and reduce labor & operating costs of power grid enterprises\cite{7}.

2. The Principle of the System

This system can implement LCAM in various sections concerning smart electric energy meters, such as production process management, delivery inspection equipment, storage management, user acceptance, on-site operation and maintenance & scrap. Relevant data interactions of such sections involve the storage and data transmission via the RFID technology and the Web-based cloud platform.

RFID tags support rapid reading and writing, mobile identification, multi-target identification, position tracking management and other functions. Solutions based on the RFID technology can realize commodity tracking and information sharing, and also increase the identification efficiency\cite{3}. In addition, the development of the RFID technology provides technological possibilities for the realization of LCAM of closed-loop smart electric energy meters.

The embedding active RFID chip makes smart electric energy meters alive. In other words, under the galvanical and non-galvanical conditions, such meters can connect with real-time apparatus data and upload data of each period to the cloud serving platform. The anti-collision mechanism of RFID can realize the following contents: simultaneous reading and writing for various channels and tags; multi-parameter settings for smart electric energy meters; rapid examination and calibration; local data collection; and online fault detection. The active RFID data has a large storage capacity and a strong real-time processing capability and can transfer & receive data within a certain distance. The establishment of the cloud platform assists clients in rapidly and conveniently making an LCAM of smart electric energy meters and conducts real-time collection, filtering, statistical analyses and report queries of a large amount of data concerning smart electric energy meters.

3. Main Structures of the System

3.1 Smart Electric Energy Meters Designed on the Basis of Active RFID Chips

Smart electric energy meters based on the RFID technology work within the UHF band, support wireless radio frequency read-write, identify specific targets and RW data via radio signals, and bear data storage functions. As managed by blocks, the storage areas of the chip can be locked respectively and protected via passwords and support password-protection RW control and low-powered RW operations. The period of data storage is no less than 100 years. The storage bears high-security and manipulation-proof functions. Such meters conform to the EPC Global Class1 Gen2(V1.2.0) Standardization and the ISO/IEC 18000-6C Protocol and also bear the Globally Unique Identification Code\cite{8}. Smart electric energy meters designed according to RFID have the following functions:

The writing and reading of various procedure information support the control of production sections & processes, undergo RFID verification, streamline instruments verifying equipment, reduce equipment calibration costs and provide basic data of procedures.

The RFID local meter collection is supported and can replace infrared-ray meter reading. Regardless of distances, locations and light intensities and without manual inputs of meter numbers (or location information), one-button meter collection can be realized via automatic reading functions of RFID.

Under the non-galvanical conditions, various parameter information of smart electric energy meters can still be read via RFID, such as manufacturer, date of production, manufacturing date, meter
number, address number, parameter, level, article attribute (electric energy meter properties) and installation location (support on-site input).

3.2 An Overall Management of Production & Manufacturing Procedures
The RFID RW system set up in all apparatus manufacturing sections achieves real-time communications between the manufacturing equipment and products (RFID smart electric energy meters) and fully controls the overall situations concerning products, such as assembly, aging, verification, inspection, storage and maintenance. Smart electric energy meters can make an automatic positioning during intelligent manufacturing processes, set corresponding procedure statuses and conduct automatic procedure management.

3.3 Automatic Calibration Device Based on RFID Wireless Communication
Getting rid of traditional RS485 and infrared communications, calibration devices and smart electric energy meters adopt the RFID radio frequency identification technology to achieve the communications between meters and verification devices, thus calibrations and inspections of meters being conducted. After production, the internal RFID chip of each smart electric energy meter has a globally unique identification code. The verification devices consecutively make the accuracy calibration of every meter via the RFID wireless RW equipment. Meter calibrations and verification data are uploaded to the RFID chip of a verified meter via the RFID channel of automatic meter calibration devices, which provides power grid users with a basis for verification comparisons. Finally, relevant inspection data of electric energy meters are uploaded to the cloud serving platform.

3.4 Storage Management System of Smart Electric Energy Meters
The storage management of smart electric energy meters is in line with the current national grid management system. As the active RFID chip bears a large storage capacity of information, a corrosion-proof feature and a strong resistance to harsh environments, the system writes key parameters (such as error, reference current, voltage, constant, manufacturer information, etc.) into RFID chips. Therefore, when you enter into or get out of storehouses, data stored in smart electric energy meters can automatically check the database of the storehouse management system, thus management errors being reduced[9]. At the same time, the delivery and distribution information of electric meters should be stored in installed chips in order to improve the transportation and installment securities.

3.5 The Collection System of Local Data of RFID Smart Electric Energy Meters
The on-site data collections of original meters are based on infrared devices, incurring more restraints and inconvenience. Without fixing locations (like infrared collection), the RFID smart electric energy meters make an automatic identification and read-write device and data transmission only via the RFID antenna (effective distance as 5 meters) installed in meters. The system can make a data RW via the RFID mode from the Bluetooth of mobile phones and upload such data to the cloud serving platform via mobile network, thus the integration management of the cloud platform being realized. The whole on-site collection process is easier and more convenient, during which a concentrated collection can be realized for more than one meter.

3.6 The Cloud Platform Management System
The complete LCAM system is an organic integration of the RFID technology under the Internet of Things, smart electric energy meters and the cloud platform system, including designs, manufacturing, examinations, calibrations, storage management, on-site operations, maintenance records and scrap processing of meters. Data traceability of life cycle periods of meters can be achieved.

The cloud management system involves the cloud platform operation evaluation system and the big data cloud platform system.
The cloud platform operation evaluation system makes a status evaluation on the whole working conditions of electric energy meters and takes corresponding measures in accordance with such evaluation. Based on a real-time acquisition of relevant data of smart electric energy meters in actual environments and in combination with error data obtained by standard meter regulations and on-site periodical inspections of the system, a comprehensive evaluation is conducted on influences of the complex and actual grid operating environments on the accuracy and reliability of meters. On the basis of analyzing status compositions and weights, a status evaluation standard is established to make operating status evaluation methods, thus an overhaul strategy for electric energy meters being put forward.

With a large data scale, a complex data structure and a high connection, smart electric energy meters fail to analyze more complex data structures through an easy scripting language pre-processing method. Therefore, data quality cannot be effectively monitored. The big data cloud platform supports a large amount of structured and non-structured data storage, provides various data digging methods, bears a flexible data integration capacity & a security visiting mechanism, and improves high-performance data analysis and processing services.

4. Designs of RFID Smart Electric Energy Meters

Based on smart electric energy meters and the addition of RFID data communication modules, the RFID smart electric energy meters aim to transmit various parameters of smart electric energy meters via high-frequency wireless. The main structure is shown as Figure 1. The RFID module is connected with the main control module via the I²C Bus. The RFID module includes the RFID radio frequency chip and antenna.

The concrete working procedures of the RFID module are shown as Figure 2. When receiving the read-write command from external read-write devices, the RFID antenna determines whether this command is relevant to this electric energy meter. If no, no measures are taken. If yes, corresponding information should be inquired according to such command, which will be transmitted to external read-write devices via the RFID antenna.

In addition, research on the RFID smart electric meters focus on the RFID Chip Protocol and the efficient utilization of corresponding storage spaces.

In order to save the storage space for integrated information, the internal data area of the RFID chip is divided into the following sub-areas according to function requirements: a parameter area, a power data storage area and an information storage area of the manufacturing section. The parameter area saves the following data: manufacturer, meter number, size and date of delivery. The power data storage saves the following data: the current combination of active power, power supply voltage, power supply current and rate times. The information storage area of the manufacturing section saves the following data: all the information of manufacturing procedures & sections.
**Fig. 1** The main structure diagram of RFID smart electric energy meters

- **Start**
- System Initialization
- Whether to receive a Read/Write Command?
  - Yes
  - No
    - Whether this command is relevant to this electric energy meter?
      - Yes
        - Inquire corresponding information according to this command
      - No
- Transmit such information via the RFID antenna
- **End**

**Fig. 2** The RF part work flow chart of RFID smart electric energy meters
5. Tests
As RFID smart electric energy meters add wireless communication modules, electromagnetic compatibility tests are extremely necessary.

Smart electric energy meters based on RFID radio frequency chips receive electromagnetic compatibility tests, especially anti-inference tests for radio frequency electromagnetic fields. According to requirements of National Standard GB/T17215, tests are conducted from 80 MHz to 1,000 MHz.

Test results are shown as Figure 3. under the electromagnetic interference from 80 MHz to 1,000 MHz, changes of all actual relative errors of RFID smart electric energy meters are less than 0.3 percent, which conforms to the requirement (no more than 3.0 percent) of National Standard. It shows that the added RFID communication module exerts a small effect on electric energy meters.

![Fig. 3 The results of RFID smart electric energy meters RF electromagnetic field immunity test](image)

The results of measurement modules that may be triggered by RFID antenna communication in an RFID smart electric energy meter has also been tested. Because the RFID antenna does not work without an external reader communication, only the influence on errors of the RFID meter is to be detected provided by different distances between the external reader and the RFID meter. The test results are shown as Table 1.

| Distance /m | Group 1/% | Group 2/% | Group 3/% | Group 4/% | Group 5/% |
|------------|-----------|-----------|-----------|-----------|-----------|
| 0.1        | 0.068     | 0.071     | 0.070     | 0.071     | 0.072     |
| 0.5        | 0.071     | 0.073     | 0.074     | 0.073     | 0.074     |
| 1.0        | 0.072     | 0.067     | 0.071     | 0.072     | 0.072     |
| 2.0        | 0.069     | 0.062     | 0.072     | 0.070     | 0.071     |
| 3.0        | 0.073     | 0.069     | 0.073     | 0.069     | 0.071     |
| 4.0        | 0.068     | 0.070     | 0.072     | 0.071     | 0.069     |
| ∞          | 0.071     | 0.072     | 0.074     | 0.071     | 0.070     |

For the 5 group tests, an external reader is placed beside an RFID meter at the following distances: 0.1 m, 0.5 m, 1.0 m, 2.0 m, 3.0 m, 4.0 m and ∞ (the reader is closed at this position). Test results show that errors of RFID meters basically lie from 0.068 percent to 0.074 percent and that such errors undergo insignificant changes after readers are closed, indicating that the communication between
external readers and installed RFID antenna exerts no influence on error measurements of RFID smart electric energy meters.

6. Conclusion
This paper applies the RFID technology and the Web-based cloud platform to establish an LCAM system of smart electric energy meters from production & manufacturing to maintenance & scrap and conducts tests of RFID meters. Test results show that RFID smart electric energy meters conform to national standard requirements.

This paper focuses on technological problems via the application of the RFID wireless technology, including apparatus error calibration and local data collection for more than one electric meter. Technological achievements in many aspects are undergoing experimental verification. This system is of greatest significance to strengthen the power demand side management of power grid enterprises and to improve the reliability evaluation system of smart electric energy meters.

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