Research on data collection key technology of smart electric energy meters

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Abstract: In recent years, smart electric energy meters are demand at 70 million to 90 million with the strong smart grid construction every year in China. However, there are some issues in smart electric energy meters data collection such as the interference of environment, low collection efficiency and inability to work when the power is off. In order to solve these issues above, it uses the RFID communication technology to collect the numbers and electric energy information of smart electric energy meters on the basis of the existing smart electric energy meters, and the related data collection communication experiments were made. The experimental result shows that the electric information and other data batch collection of RFID smart electric energy meters are realized in power and power off. It improves the efficiency and the overall success rate is 99.2% within 2 meters. It provides a new method for smart electric energy meters data collection.

1. Introduction

According to relevant statistics, from 2009 to July 2016, with the construction of “strong smart grid”, State Grid Corporation of China has accumulatively bided for 477 million smart electricity meters. The quantity of bidding for smart electricity meters exceeded 90 million sets in 2014 and 2015[1].

As a huge number of electricity meters are bided, electric quantity is acquired mainly through power line carrier, infrared communication, RS485 and other conventional communication modes. Powerline carrier communication is dependent on existing power line communication data. In case of line fault or power failure, electric quantity cannot be read from the electricity meter. The acquisition equipment needs to be manually aligned with the infrared data port of the electricity meter for infrared communication, and cannot be covered. Data is acquired only from 1 electricity meter every time with a low communication rate, and communication is interrupted in case of power failure. Long-distance wiring for RS485 communication brings about high costs, and communication is interrupted in case of power failure.

In recent years, Liu Qingchan et al designed an electricity meter data acquisition scheme combining power line carrier and wireless communication technology[2]. Xu Zhiqiang et al proposed a power line carrier system based on channel cognition which can automatically cognize and look for the optimal frequency band so as to guarantee the system reliability[3, 4]. NDLOVU proposed an OFDM based power line carrier modulation scheme for forward error correction, thus improving interruption and impulse noise of high-speed narrow-band data transmission and other problems[5]. Fu Wenyuan et al designed a smart meter reader circuit based on infrared communication so as to enlarge the communication distance for infrared data acquisition[6]. Du Yan et al introduced laser aiming and
infrared concentration technology into infrared communication of electricity meter, thus improving data acquisition efficiency\cite{7}. The above methods are improved based on the existing communication mode, without thoroughly solving such problems as low data acquisition efficiency and communication interruption in case of power failure.

In addition, Wu Xin designed a ZigBee short-distance wireless communication based smart three-phase electricity meter system\cite{8}. Cong Le et al researched the meter reading method combining infrared communication and ZigBee technology\cite{9}. This technology cannot be applied to solve communication interruption in case of power failure.

RFID communication technology is combined with smart electricity meter. Electric quantity of the electricity meter may be stored into the RFID chip at intervals as required. When electric quantity and other information are acquired, as RF signal can penetrate a non-metal object without influences from space environment, data may be directly acquired, and electric quantity may be read from the RFID chip. Information may be acquired from multiple electricity meters at one time without influences from line fault and system power failure, thus significantly improving the data acquisition efficiency.

2. RFID Communication Technology

Radio frequency identification (RFID) communication technology is a wireless communication based automatic identification technology, can be applied to automatically identify target objects and acquire relevant data based on RF signal, and can identify high-speed moving objects and multiple tags without manual intervention\cite{10}.

RFID system generally comprises reader, transmitting antenna, tag antenna and tag chip. Figure 1 is a schematic diagram of RFID communication. The reader can send RF signals with a certain frequency (generally between 860MHz and 960MHz) through transmitting antenna. The tag antenna receives reading/writing orders received through electromagnetic coupling within the effective reading/writing distance and such orders are transmitted to the tap chip. Relevant data are read by the tag chip depending on received energy, and are reversely sent to the reader through antenna. The reader can complete decoding according to received data, and provide corresponding processing and control according to different settings. RFID technology is characterized by convenient and rapid reading, large data capacity, wide application and long service life, and is not affected by non-metal barriers in space during communication.

RFID electronic tag is classified into passive tag and active tag. A passive electronic tag is widely applied in logistics, warehousing and other fields\cite{11, 12}. In the power industry, RFID passive electronic tag technology\cite{13, 14} is often applied for management of such power materials as common single-phase, three-phase electricity meter and centralizer such as warehousing, checking and storage, and some latest warehousing management systems of the metering center have been deemed as a necessary management means\cite{15}.

Considering that the active electronic tag is large in volume, a passive tag is conveniently placed with a long communication distance compared with passive tag, and is widely applied in such fields as
vehicle positioning and large warehouse management.

3. RFID Smart Electricity Meter
RFID smart electricity meter is based on common smart electricity meter, and is additionally provided with RFID data communication unit so as to transmit various data of the smart electricity meter through high-frequency wireless signal.

RF communication of the RFID smart electricity meter is shown in Figure 2. The RFID communication unit is connected to the smart electricity meter MCU so as to achieve bi-directional data communication. The RFID communication unit consists of RFID tag chip and RFID RF antenna, and all equipment is placed inside the shell of the electricity meter, without changing the external structure of the electricity meter.

Figure 2 Schematic Diagram for Communication of RFID Smart Electricity Meter

Impinj X-2K shall be used as RFID tag chip, and is an ultra-high-frequency RFID active tag chip conforming with Gen2 standards with a working frequency of 860 MHz-960 MHz and is provided with 2176 bits internal storage and one I2C bus interface. It can read external data under active and passive conditions, in which the chip has a sensitivity of -19.5dBm and -17dBm respectively under active and passive status.

Different from previous RFID active tag chips, X-2K can achieve data communication through I2C bus and smart electricity meter, and store such information as meter number and electric quantity of the smart electricity meter to the X-2K chip at intervals (perhaps several seconds or several days) according to actual demands. The RFID reader can directly read data from the X-2K chip during data acquisition so that data can be acquired even during power failure. In addition, the RFID reader also can write a command into the X-2K chip according to DL/T 645 protocol, and the electricity meter will read and execute relevant commands at regular intervals after power-on. Besides, in consideration of particular characteristics of RFID communication, even if the electricity meter is placed into a box, data can be acquired via glass plate or other metal windows if any.

In particular, data stored into the X-2K chip is specially encrypted. During communication with the RFID reader, data are still kept encrypted. Electric quantity and other information can be displaced upon encryption by authorized equipment so as to guarantee the information safety of the users and power grid.

4. Experimental Test
Three tested electricity meters and 1 set of data acquisition equipment are prepared for data acquisition experiments on the above electricity meter. Acquired data include meter number, peak electric quantity, normal electric quantity, valley electricity quantity and total electric quantity. Various data of 3 tested electricity meters are shown in Table 1.
Table 1 Data of Electricity Meter

| Major parameters      | Tested Electricity Meter 1 | Tested Electricity Meter 2 | Tested Electricity Meter 3 |
|-----------------------|----------------------------|----------------------------|----------------------------|
| Meter number          | 151023000688               | 151023000697               | 151023000653               |
| Peak electric quantity (kWh) | 0.51                      | 0.27                      | 1.33                      |
| Normal electric quantity (kWh) | 1.08                      | 0.32                      | 2.47                      |
| Valley electric quantity (kWh) | 0.00                      | 0.11                      | 0.32                      |
| Total electric quantity (kWh) | 1.59                      | 0.70                      | 4.12                      |

Data are acquired from 3 tested electricity meters respectively under power-on and power-off status respectively for 100 times at different distances (0.2m, 0.5m, 1.0m, 1.5m and 2.0m), and the frequency of successful data acquisition is recorded, as shown in Tables 2 and 3.

Table 2 Data Acquisition Experiment of Electricity Meter under Power-on Status

| Acquisition Distance (m) | Frequency of Successful Data Acquisition by Electricity Meter |
|--------------------------|-------------------------------------------------------------|
|                          | Tested Electricity Meter 1 | Tested Electricity Meter 2 | Tested Electricity Meter 3 |
| 0.2                      | 100                        | 100                        | 100                        |
| 0.5                      | 100                        | 100                        | 100                        |
| 1.0                      | 100                        | 100                        | 100                        |
| 1.5                      | 99                         | 100                        | 100                        |
| 2.0                      | 97                         | 100                        | 99                         |

Table 3 Data Acquisition Experiment of Electricity Meter under Power-off Status

| Acquisition Distance (m) | Frequency of Successful Data Acquisition by Electricity Meter |
|--------------------------|-------------------------------------------------------------|
|                          | Tested Electricity Meter 1 | Tested Electricity Meter 2 | Tested Electricity Meter 3 |
| 0.2                      | 100                        | 100                        | 100                        |
| 0.5                      | 100                        | 100                        | 100                        |
| 1.0                      | 98                         | 100                        | 98                         |
| 1.5                      | 98                         | 99                         | 99                         |
| 2.0                      | 95                         | 95                         | 100                        |

According to above data, the success rate for data acquisition by the electricity meter is 99.7% and 98.8% respectively under power-on and power-off status within 2m. During analysis of the reason why the success rate under power-off status is lower than that under power-on status. Energy for transmitting data by RF antenna of the electricity meter under power-off status is totally from the reader. Energy for transmitting data by the electricity meter under power-on status is also from power supply of the electricity meter in addition to reader. The larger the energy, the further the communication distance and the better the effect, namely, the success rate for data acquisition is higher.
at the same distance. As the distance increases, the frequency of successful acquisition under these two statuses is gradually decreased. According to the above two experiments, the comprehensive success rate for data acquisition by RFID smart electricity meter within 2m is 99.2%.

5. Conclusion
In view of shortcomings of existing methods for data acquisition by the smart electricity meter, an RFID communication technology based method for data acquisition by the smart electricity meter is proposed. This method is not affected by non-metal barrier, line fault and system power failure. Test results show that the comprehensive success rate for data acquisition within 2m is 99.2%, and information of various electricity meters can be acquired at one time, thus significantly improving the data acquisition efficiency compared with infrared method and other methods. A new method is proposed for data acquisition by the smart electricity meter. With the construction of national strong smart grid and promotion of the reconstruction of smart power grid at abroad, RFID smart electricity meter as a terminal has extensive market prospects.

References
[1] LIU Weilin, BUMILLER G, GAO Hongjian. Power line communications and its application[C]. 2014 18th IEEE International Symposium on Power Line Defined PLC System, 2014.
[2] NDLOVU M M C. A permutation coding and OFDM-MFSK modulation scheme for power-line communication[D]. University of the Witwatersrand, 2015.