A Study on Watt-hour Meter Data Acquisition Method Based on RFID Technology

Xiangqun Chen¹, Rui Huang¹, Liman Shen¹, Hao Chen¹, Dezhi Xiong¹, Xiangqi Xiao¹, Mouhai Liu¹, Renheng Xu²

¹State Grid Hunan Power Supply Service Center(Metrology Center), Changsha 41000, China
²Harbin Research Institute of Electrical Instrumentation, Harbin 150028, China

Abstract: Considering that traditional watt-hour meter data acquisition was subjected to the influence of distance and occlusion, a watt-hour meter data acquisition method based on RFID technology was proposed in this paper. In detail, RFID electronic tag was embedded in the watt-hour meter to identify the meter and record electric energy information, which made RFID based wireless data acquisition for watt-hour meter come true. Eventually, overall lifecycle management of watt-hour meter is realized.

1. Introduction
Traditional far infrared (IR) meter reading is under the influence of metering box cover occlusion so that the meter cannot be read under the circumstance that we stand below the box; if the relevant deviation angle is too large, it may go beyond the distance supported by far IR communication, which further incurs difficulties in acquiring data of the watt-hour meter¹⁻². However, the watt-hour meter data acquisition method based on RFID was utilized to embed RFID electronic tags in the meter for the purpose of identifying the meter, recording electric energy information and finally implementing RFID based wireless data acquisition for watt-hour meter. It solves the problem that conventional far IR meter reading suffers deficiencies of angular and window limitations. Regardless of angles, the meter can be read normally as long as it falls into the RFID communication distance range. As a result, it is no longer a problem to read watt-hour meters some of which cannot be read or cannot be read easily. With regard to such a data acquisition method, the most important thing is to solve problems related to built-in RFID electronic tags of the watt-hour meter. Moreover, RFID electronic tags are constituted by RFID tag chips and antennas for communication. Below, several major issues associated with RFID based watt-hour meter data acquisition were respectively described.

2. RFID tag chip
Impinj Monza X-2K Dura has been selected for RFID chip tag. It is a kind of ultrahigh frequency (UHF) RFID tag chip with a nonvolatile memory (NVM) of 2176bits and an I2C interface; furthermore, its high-capacity memory area (2k) and I2C interface cannot be found in ordinary RFID tag chips³. Structure of Monza X-2K Dura tag chip is as follows.
Fig. 1 Tag chip structure diagram

Instructions of each foot of tag chips have been presented in Tab. 1.

| Name   | Description             |
|--------|-------------------------|
| RF1P   | Differentiated RF outlet 1 |
| RF1N   |                         |
| RF2P   | Differentiated RF outlet |
| RF2N   |                         |
| DCI    | Input voltage           |
| SCL    | I2C time input          |
| SDA    | I2C data input          |

Memory area of Monza X-2K Dura tag chip is primarily divided into four parts\textsuperscript{[4-5]}, namely, EPC (product code), TID (unique identifier), USER (user area) and Password (password area). Among them, while TID can be used as the unique identification of watt-hour meter, EPC to encode the watt-hour meter according to certain coding principle. USER accommodates 2k information; therefore, basic information of the watt-hour meter is stored in this area. In password area, passwords are established to control reading and writing of electronic tag and cancel/modify relevant permission.

During I2C communication, Monza X-2K Dura tag chip is the slave device; MCU of the watt-hour meter takes the initiative to send commands so as to realize communication with the tag chip.

For simulation and computing, load impedance of a port has been modeled in this paper by virtue of a method similar to a large signal model given in Fig. 2. It acts as conjugate of optimal source impedance, but is not equivalent to input impedance of the chip. Such a method is necessary for non-linear and time-varying radio-frequency (RF) circuit.

Fig. 2 The large signal model
3. Design of antennas interface circuit

Antenna is critical to RF communication and its structure has been shown in Fig. 3.

![Fig. 3 Antenna structure diagram](image)

Tag antenna mainly has two functions[6]. Firstly, energy is effectively transferred to the tag chip so that the chip has enough power to run normally. Secondly, energy with tag information is scattered back to reader antenna, in which case, the reader system can identify the tag and process relevant data. To solve problems mentioned above, impedance matching between tag antenna and chip should be investigated[7].

3.1 Equivalent circuit of antenna

During operation, antenna can be equivalent to internal resistance of a power pack. Model of the equivalent circuit has been given in Fig. 4.

![Fig. 4 Antenna equivalent circuit](image)

In this figure, Vin refers to voltage source required by the equivalent antenna to receive signals, Rr to radiation resistance of antenna, R1 to loss resistance of antenna, L1 to equivalent inductance of antenna and finally C1 to equivalent capacitance of antenna.

3.2 Matching network

In RFID system, matching between antenna and tag chip becomes increasingly important as operating frequency goes up little by little[8]. Antenna is employed to transfer the maximum energy to tag chip, which requires carefully designing matching circuit between them[9]. In this paper, equivalent impedance of the known standard half wave dipole antenna was 73+j42.5Ω. From the perspective of conjugate matching, it would be best that load impedance was 73-j42.5Ω. Through testing, input impedance of the chip was 6.18+j35Ω. Hence, series capacitance should be additionally added and connected so that resonant frequency of the circuit could be matched to 915MHZ. In this way, antenna is able to receive the maximum energy in this condition.

Quality factor of the antenna is expressed in the equation below.

\[ Q = \frac{\omega_0}{B} = \frac{f_0}{BW} = \frac{\omega_0 L}{R} = \frac{1}{\omega_0 CR} = \frac{1}{R \sqrt{L/C}} \]  \[ (1) \]
According to Equation (1), Q value of resonance circuit is assumed to be 5 provided that the fixed resonant frequency is 915MHz; in this case, inductive reactance of the antenna can be written into Equation (2).

\[ j\omega L = j73 \times 5 = j365\Omega \]  

(2)

Capacitive reactance is,

\[ \frac{1}{j\omega C} = j42.5 - j365 = -j322.5\Omega \]  

(3)

Under the circumstance that resonant frequency is 915MHz, inductance and capacitance values corresponding to inductive reactance and capacitive reactance figured out above are 63.49nH and 539.35fF respectively. Equivalent circuit obtained has been presented in Fig. 5.

Fig.5 The half wave dipole antenna equivalent circuit

To achieve optimal matching, cascade equivalent load in the back end should be 73-j42.5Ω. In this context, circuit configuration is that shown in Fig. 6.

Fig.6 The best matching circuit

Testing impedance of the chip is 6.18+j35Ω. In a condition of 915MHz, it can be equivalent to 6.18Ω resistance and 6.18nH inductance in series connection. Through series connection of resistance and capacitance, impedance of back-end circuit can reach a value required by matching so as to satisfy requirements of optimal matching and further acquires the maximum energy. Through computing, resistance that requires series connection is 66.82Ω and capacitance is 2.25pF. Fig. 7 is the actual optimal matching circuit.
Dependent on above procedures, matching between antenna and chip can be completed preferably. Resultantly, RFID electronic tag possesses functions required making preliminary preparations for RFID based watt-hour meter data acquisition and overall lifecycle management of watt-hour meter.

4. Watt-hour meter data acquisition method based on RFID technology

The system consists of the watt-hour meter to be read and hand-hold meter reading device. Built-in RFID electronic tag of the watt-hour meter is constituted by RFID tag chip and antenna. Moreover, RFID electronic tag is embedded into PCB of the meter and communicate with its MCU through I2C acquiring its electric energy information further stored in electronic tag register. Additionally, wireless communication is implemented between hand-hold meter reading device and the RFID electronic tag. After electric energy information in electronic tag register has been achieved, watt-hour meter data acquisition is fulfilled. Flow chart of RFID based watt-hour meter data acquisition.

In addition to connection between antenna of the electronic tag and antenna pin of Monza X-2K chip, I2C communication is also conducted by connecting SDA and SCL pins of Monza X-2K chip to SDA and SCL pins of MCU. Through experimentation, MCU information can be written into USER register of RFID electronic tag for storage. Hand-hold meter reading device communicates with the electronic tag in a wireless manner to read electric energy information stored in the register. Besides, basic information of the watt-hour meter can be also written in according to the tag and relevant data stored in the database.

5. Conclusion

In line with the RFID based watt-hour meter data acquisition method proposed in this paper, RFID chip was integrated into circuit board of the meter to communicate with MCU and realize mutual communication between the meter by virtue of RFID read-write equipment wirelessly and data reading/storage. Since the production of watt-hour meters, various information of them has been noted down by RFID read-write equipment. After they leave the plant, unique identification of RFID chip is utilized to perform depot management of watt-hour meter warehouse dependent on such equipment, which is featured with precise positioning, high management efficiency, clear information at a glance and fast data updating. After the watt-hour meter has been put into operation, hand-hold RFID read-write equipment is adopted to read the meter on site in a more convenient and more accurate manner. Besides, track management function has been also realized, such as data modification. Data can be uploaded to the management system platform on the spot to realize real-time update. From production to scrapping of each watt-hour meter, all information of it is stored in RFID chip first and then uploaded to the management system platform dependent on the RFID read-write equipment. In the end, overall lifecycle track management of watt-hour meters is implemented.

References
[1] FAN Wen-bing, GE Zheng, WANG Yao. Design and simulation of UHF RFID System[J]. Computer Engineering, 2010(17): 30-32.
[2] Yang Rui-xia. Design and implementation of remote reading Watt-hour meter based on GPRS[J]. Electrical Measurement & Instrumentation, 2007(12): 22-26.
[3] D.Mawhinney, Microwave Tag Identification Systems. RCA Rev.Vol4, No.4, pp. 589-610.
[4] Zhu Hai-long, Lai Xiao-zheng, Dai Hong-yue, Lai Sheng-li, Wang Xin. Analysis of a front-end circuit configuration for long range LF RFID Reader[J]. Electrical Measurement & Instrumentation, 2008(5): 55-60.
[5] Zhi Ning Chen,Xianming Qing,Hang Leong Chung."A Universal UHF RFID Reader Antenna,". IEEE Microwave Theory and Techniques . 2009.
[6] Qing Xianming, Yang Ning. A Folded Dipole Antenna for RFID, IEEE Antennas and Propagation Society International Symposium, 2004, 1: 97-100.
[7] Yang Zi-jiang. Dual Printed Dipole Reader Antenna Design for UHF RFID Near-field Applications[D]. Beijing University of Posts and Telecommunications, 2011.
[8] Duan Yan-min. Design and Analysis of Miniaturized RFID Antennas in UHF-Band[D].SouthWest Jiaotong University, 2010.
[9] Zhong Fang-qiang. Dissertation Submitted to Hangzhou Dianzi University for the Degree of Master[D]. Hangzhou Dianzi University, 2011.
[10] Yun-Taek Im, Jea-Hee Kim, Wee-Sang Park."Matching Techniques for Miniaturized UHF RFID Loop Antennas,". IEEE Antennas and Wireless Propagation Letters . 2009.