Design of Smart-Meter data acquisition device based on Cloud Platform

Xiangqun Chen¹, Rui Huang¹, Liman Shen¹, Hao chen¹, Dezhi Xiong¹, Liu Liping¹, Chenglin Zhang³, Renheng Xu²

¹ State Grid Hunan Electric Power Limited Company Power Supply Service Center (Metrology Center), Hunan Province Key Laboratory of Intelligent Electrical Measurement and Application Technology, Changsha 410004, China.
² Harbin Research Institute of Electrical Instrumentation, Harbin 150028, China
³State Grid Hunan Technical Training Center

Abstract: In recent years, the government has attached great importance to ‘Four-Meter Unified’ Project. Under the call of national policy, State Grid is participate in building ‘Four-Meter Unified’ Project actively by making use of electricity information acquisition system. In this paper, a new type Smart-Meter data acquisition device based on Cloud Platform is designed according to the newest series of standards Energy Measure and Management System for Electric, Water, Gas and Heat Meter, and this paper introduces the general scheme, main hardware design and main software design for the Smart-Meter data acquisition device.

1. Introduction
In recent years, relevant government departments have placed great importance to the promotion of “all-in-one meters” of public services. To facilitate the development of Energy Internet, the National Development and Reform Commission, the National Energy Administration, and the Ministry of Industry and Information Technology have jointly formulated Guidelines for Promoting Internet Plus Smart Energy Development. In the meanwhile, they have pointed out that “we should enrich the implementary functions of the advanced measurement systems of smart terminals, promote remote automatic collection and reading of water, gas, heat and electric energy, and apply all-in-one meters in the guidelines for promoting the popularization of smart terminals and access facilities. Responding to the call of the national policy, State Grid Corporation of China takes the lead in expediting the implementation of “all-in-one meters” as a key program and providing more services that are “convenient to the people, oriented to the people, and beneficial to the people”. By comprehensively using and upgrading its users’ electricity data collection system platform, State Grid has implemented concentrated reading of electric, water, gas, and heat meters, thus improving social public service level. In this paper, a smart meter data collector is designed according to the latest series standards of Energy Measure and Management System for Electric, Water, Gas and Heat Meters and it can collect, manage, and transmit the data of electric, water, gas and heat meters.

2. Design Scheme for Smart Meter Data Collection

2.1 Data collection mode of the smart meter
Current smart watt-hour meters use power line carriers and RS-485 for data communication in
accordance with DL/T645-2007 Multi-function Watt-hour Meter Communication Protocol. The other three meters are more complicated. Generally, water meters, gas meters and heat meters are divided into ordinary mechanical meters, IC card prepaid meters, and remote smart meters. By communication mode, remote smart meters are further classified into meters based on wired communication and the ones based on wireless communication [1]. In the present market, RS485 bus and M-Bus are the major wired communication modes while micro-power wireless transmission is the major wireless communication mode. However, with LoRa and NB-IoT emerging and becoming mature, new remote smart meters are under development. As for communication protocols, water, gas, and heat meters mainly follow CJ/T188-2004 Technical Requirements of Utility Meters Data Transmission and non-standard CJ/T188 user-defined protocols. The data collector has an RFID communication module that supports ISO 18000 6C and EPC Class 1 Gen 2 standards and it can communicate data with RFID handheld meter reading devices.

2.2 Cloud platform management system for electric, water, gas and heat energy measurement

The series standards of T/CEC122-2016 Energy Measure and Management System for Electric, Water, Gas and Heat Meters were issued by China Electricity Council in October 2016 and formally put into effect on January 1, 2017. These series standards stipulate system structures, functional requirements, equipment requirements, communication protocols, and test methods, and direct the construction of smart meter data collection systems effectively. With uniform data collection terminals and communication channels, data of smart meters can be remotely collected automatically, and a comprehensive data management platform is constructed for electricity, water, gas, and heat utility meters.

The cloud platform management system introduced in this program effectively controls the development costs of data collection master stations. What’s more, cloud services can provide more reliable data storage and management applications, thus largely reducing development workload and duration as well as future upgrade and maintenance costs of data collection master stations.

2.3 Design scheme for smart meter data collectors

As part of the management system for electric, water, gas and heat energy measurement, a smart meter data collector works as a connection between the uplink and the downlink, which collects, parses, stores, and processes smart meter data as well as communicates with the concentrator. It uploads the processed smart meter data to the concentrator and receives commands issued by it [3].

According to the foregoing smart meter data collection methods and communication protocols, the smart meter collector is designed as a split type, namely, a main board module and an external module. In the main board module, STM32 SCM serves as the main control unit, containing a power module, a storage module, a clock module, and several communication modules and interfaces. The communication module contains 2-wire RS485, 1-wire M-Bus master module, 1-wire M-Bus slave module, 1-wire infrared module, 1-wire pulse module, and so on. The uplink communication protocol of the collector conforms to the transmission protocol requirements in Appendix B of T/CEC122.32-2016 Energy Measure and Management System for Electric, Water, Gas and Heat Meter Part 3-2: Acquisition Device Technical Specification, and the downlink supports DL/T645, CJ/T188-2004, and so on. The main board module is set with several external module slots to support the automatic identification function of the communication module; and its external module contains carrier module, RFID communication module, and micro-power wireless communication module.

3. Hardware Design for Smart Meter Data Collector

3.1 Main control module
STM32F103VCT6, a high-performance 32-bit microcontroller based on ARM Cortex-M3 core, is selected as the main control unit (MCU), with an operating frequency of 72MHz and a built-in high-speed memory (a flash memory of up to 256K bytes and an SRAM of 64K bytes). The
microcontroller has powerful on-chip resources including three 12-bit ADCs, two 12-bit DACs, four universal 16-bit timers, and two 16-bit PWM advanced timers with dead control, as well as thirteen communication interfaces: two \text{i}^2\text{C} interfaces, three SPI interfaces, two \text{i}^2\text{S} interfaces (multiplexed with SPI), one SDIO interface, five UART interfaces, one USB2.0 full-speed interface, and one CAN interface \cite{4}. By virtue of abundant communication interfaces, STM32F103VCT6 can perfectly meet the uplink, downlink and local communication demands of the smart meter data collector.

3.2 Storage module
In this module, AT25DF321 is used as memory chip. AT25DF321 is an SPI serial flash memory with a storage capacity of 32MB, a single power supply of 2.7V-3.6V, and a maximum clock frequency of up to 70MHz. It can carry out 4KB/32KB/64KB block erase or chip erase, byte/page programming (1~256 bytes), and 100,000 times of rewriting. Its power consumption is low, read operation current is 5mA, and its deep power-down current can drop to 5μA with no data lost and even keeping data for 20 years at most.

3.3 Communication module
On the hardware circuit, the biggest difference between the smart meter data collector and the traditional State Grid I and II collectors is that M-Bus module, micro-power wireless module and RFID module are added to the original collector. With these changes, the module can collect data of electric, water, gas and heat meters and transmit data to RFID handheld meter reading devices.

3.3.1 M-Bus module
M-Bus is specially designed for data bus transmitting information for energy-consuming meters and counters. This module adopts a master-slave half-duplex asynchronous bus communication system. In other words, only if the central master sends an inquiry can the slave transmit data to the master. The module consists of a master, a slave, and twisted pair cables. The communication baud rate ranges from 300bps~9600bps. The main features of M-Bus are as follows: 1. The two-wire bus has no polarity and the arrangement of wires is simple; 2. Using unique electrical level features to transmit digital signals, it features great anti-jamming capability and long transmission distance; 3. The master can supply power to the slave via communication lines remotely, which can reduce maintenance costs; 4. Its structure is bus topology, which is convenient to expand and features low networking costs \cite{5}. The smart meter data collector M-Bus module of this design consists of two parts, namely, master module and slave module. The master module is constructed by discrete components such as resistors, capacitors, and transistors, which can meet the electric parameters of the master M-Bus interface specified in T/CEC122.32 protocol. The transmission voltage $V_{\text{mark}}$ ranges from 22V to 42V, the no-load voltage $V_{\text{space}}$ ranges from 12V to $(V_{\text{mark}}-10V)$, the receiving current $I_{\text{mark}}$ ranges from 0mA to 1.5mA, and the no-load current $I_{\text{space}}$ ranges from $(I_{\text{mark}}+11mA)$ to $(I_{\text{mark}}+20mA)$.

When the smart meter data collector transmits data via M-Bus, the transmitting port TX of the master circuit is set to a high electric level, the transistor Q1 is in the cut-off state, and the base voltage of Q3 is 0V, with Q3 also in the cut-off state. Since R24 and R25 split the voltage, Q2 has a base voltage of about 10.7V and the conduction voltage of Q2-8050 is 0.7V. Thus the voltage on the MUBS+ side is about 10V, and the voltage of R21, that is, the voltage difference between Mbus+ and Mbus-, is about 28V, right in the transmission voltage range of 24V~36V. When there is no load, the transmitting port TX of the master circuit is set to a low electric level, and the transistors Q1 and Q3 are both in the conducting state. Since Q3 is in the conducting state, the grounded base of Q2 is at the low electric level, while the voltage of Q2 transmitter is about -0.7V, which is because Mbus- is directly connected to VSS. At this moment, the voltage between both ends of R21 is about 17.3V. Thus, voltage difference between the transmission voltage and the no-load voltage is about 10.7V. Despite of the changes of R21’s voltage along with the increase or decrease of VSS, the transmission voltage and the no-load voltage both meet the requirements of T/CEC122-32 as long as VSS $\leq$ 0V.

In the receiving circuit, a resistor R27 is connected in series on Mbus+ line as a current sampling
resistor, with one end being connected to VCC to boost voltage and power of VCC, so as to improve the driving capability of the receiving circuit. Although the other end of R27 is connected to the Q2 collector, the work of the transmission circuit will not be affected. C22 and R28 are used for high-pass filtering, which filter out interferences caused by external changes and allow the sampled signals with a baud rate of 300~9600 bps to pass by. Q4 and Q5 are to amplify and reshape waveforms of the sampled current.

M-Bus slave module adopts TSS721A of TI Company, which is a slave communication chip developed by TI specifically for M-Bus, completely meeting EN1434-3 standard. The internal interface circuit of TSS721A is self-adaptive to several electric levels between the master and the slave. Featuring non-polarity connection and supporting remote power supply, the slave can be supplied with power by bus or batteries, and on the inside, there is 3.3V constant voltage source. It supports half-duplex UART protocol, and the baud rate can be up to 9600 bps.

3.3.2 Micro-power wireless module
According to the requirements in Energy Measure and Management System for Electric, Water, Gas and Heat Meter Part 4-2: Ultra Micro-power Wireless Communication Protocol, the micro-power wireless module of the smart meter data collector adopts Si4CON-C, a high-performance low-current transceiver designed and developed by SILICON specially for the smart meter market of China. Si4438-C has an operating frequency range of 425~525MHz and a receive sensitivity of -124dBm. It supports (G) FSK and OOK modulation and has a maximum output power of +20dBm. In the meanwhile, it also achieves extremely low consumption of effective current and standby current. Si4438 communicates with MCU through a standard 4-wire SPI, namely SCLK, SDI, SDO, and SEL. SPI interface can work at a frequency of up to 10 MHz. The master module writes data through SDI pin and reads data from the device on SDO output pin. SEL pin should be lowered so as to initiate SPI commands.

3.3.3 RFID communication module
For some electric energy meters with RFID communication function, this smart meter data collector is designed with an RFID communication module so that data can be transmitted to handheld RFID meter reading devices. The RFID module adopts X-2K Dura chip of Impinj. X-2K Dura is a UHF RFID chip with 2176-bit nonvolatile memory, thus conforming to EPC Class 1 Gen 2 and ISO 18000-6C standards. Its operating frequency ranges from 860MHz to 960MHz. In passive conditions, the sensitivity of single RF antenna signals is -17dBm, and that of dual RF antenna signals is -19.5dBm. In active conditions, the sensitivity is up to -24dBm. Communicating with the master control chip through I2C bus, X-2K Dura can store metering data and meter’s local information collected by the data collector to the nonvolatile memory. When RFID handheld reading devices are collecting data, they can read data from X-2K Dura chip directly.

4. Software Design for Smart Meter Data Collector
4.1 Main program of the collector
After the data collector is powered on, all modules and I/O ports are initialized, and then the main program is started and waits for interrupt response \(^6\). When the communication module of the data collector receives a request frame of the concentrator, the uplink communication module of the data collector will respond to the interrupt. And then it checks whether the received data frame is legal or not and uses protocol parsing program to parse it. If the content of the data frame is to read frozen data, then the program of the storage module will be started, so that the corresponding frozen data can be read and then packaged according to the standard protocol frame format. At last, the data is sent to the concentrator through the uplink communication module. In the case that the content is to read real-time data rather than frozen data, the data of electric, water, gas, and heat meters will be collected based on the data identifier parsed by the data frame. And the data collector goes back to the main
program module and waits for the interrupt response of downlink collection communication module. If the meter replies the data frame, data will be parsed and packaged and then uploaded to the concentrator. If interrupt response is not given within the specified time, the data collector will upload an error frame to the concentrator \cite{7} and then return to the main program module and wait for the next interrupt response.

4.2 Communication module automatic identification program

There are several standard communication module interfaces on the main board module of the smart meter data collector, and thus the collector has local communication module identification function \cite{8}. When the communication module is inserted into any position of the communication module on the collector, the communication module monitoring program will be started immediately. If MCU receives the module identification communication protocol frame reported by the communication module, it will parse it, ask the protocol’s permission to enter the uplink module management flow according to the communication address of the uplink communication module, and then complete automatic identification. If MCU does not receive the data frame reported by the communication module, it will issue an automatic identification communication protocol frame, and then carry out protocol parsing after receiving a response frame from the communication module. And then, it will enter the downlink module management process by applying the collector downlink communication module self-identification communication protocol. After that, it completes the automatic identification, and at last ensures normal communication between the main board module and the communication module \cite{9}.

5. Conclusion

This smart meter data collector is designed by referring to the working principles of State Grid I collectors and Energy Measure and Management System for Electric, Water, Gas and Heat Meter. It takes STM32F103 as the control core, and adopts modular design on its hardware, realizing data collection, transmission, and storage functions of electric, water, gas, and heat meters. Its software adopts structural design concept, which facilitates the programming, reading, modification, and subsequent upgrade and maintenance of programs. As the State Grid Corporation of China is implementing the “all-in-one meters” program and using the existing power system cloud collection platform to collect data from electric, water, gas, and heat meters step by step, the smart meter data collector is offering high practical and promotion values as an important part of the system.

Reference

[1] Hua Jun. “Four-Meter Unified” Collection Principle and Its Future Development[J]. Power & Energy, 2016.37(4):445-447.
[2] T/CEC 122.1-2016: Energy Measure and Management System for Electric, Water, Gas and Heat Meter Part1: General consideration[S].
[3] Song Fang, Li Xiaowei. Four Table One Set Copy System Based on Power Line Carriertechnology[J]. Times Agricultural Machinery, 2016,43(5): 52-53.
[4] ZHANG Qinghui, ZHU Yafeng. Design and Implementation of Automatic Meter Reading System Acquisition Terminal Based on STM32[J]. Journal of Qingyuan Polytechnic, 2012,5(6): 34-37.
[5] Wang Qingshan. Design and Realization of Remote Meter Reading System based on M-BUS[D]. Zhejiang: ZHEJIANG UNIVERSITY, 2013:12-13.
[6] Ding Yi, Hou Guoping, Qi Sixue, Li Guohua, Zhao Wei. A four-meter collector applied in automatic meter reading[J]. Electrical Measurement &Instrument, 2003,45(11):11-14.
[7] Ma Yaohui, Zhu Qing, Sheng Haibo, Pan, Ping. Design of Mrico-Power Wireless Collector on CC1110[J]. Computer Systems & Applications, 2010,19(4):212-215.
[8] T/CEC 122.1-2016: Energy Measure and Management System for Electric, Water, Gas and Heat Meter Part3-2: Acquisition Device Technical Specification[S].
[9] Li Hongbo, Li Guoliang. The Collector Design of Electric Meter based on STM32[J]. Journal of Xingyi Normal University for Nationalities, 2016,2:112-115.