Design of Online Calibration Device for Electric Energy Metering Based on GPS Synchronous Sampling

Ying Wu¹, a, Chongming Chen¹, *, Dongfang Yao¹, b, Rui Cao², c

¹EHV Maintenance & Test Center, China Southern Power Grid Company Limited, Guangzhou 510660, China
²Accupower Technologies Co., Ltd, Taiyuan 030006, China

*Corresponding author e-mail: chenchongming@im.ehv.csg, awuying@im.ehv.csg, yaodongfang@im.ehv.csg, raytsao@naccupower.corn.cn

Abstract. The error checking of electric energy meter is the basic function of on-line monitoring system of electric energy metering device. A kind of on-line error checking device for electric energy metering system of digital substation is studied. It includes signal sampling module, remote pulse acquisition module, GPS synchronization module and wireless communication module. The hardware design scheme and software design idea of the main link are introduced in detail. DDS power frequency conversion circuit is designed with AD9850 chip. The designed system has the function of high and low range adjustment of input voltage and current, and the error accuracy is better than 0.05, which can greatly improve the calibration efficiency.

1. Introduction
With advances in communication technology and computer technology, energy metering devices are also being upgraded. The online monitoring and remote calibration system of the energy metering device is also developing towards intelligent, multifunctional, wireless transmission, etc. [1-5]. The electric energy metering device is composed of electric energy meter, PT and its secondary circuit, CT and its secondary circuit. The basic functions of the online monitoring system now cover online calibration of electric energy meter, abnormal condition monitoring of PT secondary loop and CT II. Sub-loop abnormal condition monitoring, etc. [6-8], the research object of this paper is the on-line calibration system of the energy meter of the gateway. The traditional method of checking the error of the electric energy meter is to compare the measured values of the check meter and the standard meter to obtain the electric energy metering error. The energy metering systems of different substations have great differences. The distance between the voltage collection port, current collection port and electric energy meter on the site may be several hundred meters. In order to save the cost of the electric energy metering device online monitoring system and avoid the on-site wiring construction, an on-line calibration device for electric energy meter error based on high-precision GPS synchronization signal was developed.

2. Electric energy meter online verification system
As shown in Figure 1, in order to verify the metering error of the energy meter, there are generally standard source method and standard table method. Since the PT terminal box and the CT terminal box have a certain distance, the voltage source and the current source synchronized by the GPS are used...
together to realize the function of the standard source. The sync signal source and the host located in the substation room together form a local area network to transmit data through the wireless router. The computer interacts with the synchronization source and the remote pulse capture device through the local area network to realize automatic verification of the energy meter.

The online calibration process of the electric energy meter can be described as follows: the PT and the CT extension respectively collect real-time three-phase high-precision voltage and current signals, and the signal at this time is the input signal of the measured meter, and the measured meter outputs the electric energy pulse to obtain the measured electric energy. At the same time, the PT extension and the CT extension send the sampled value with the time-scale information to the remote pulse capture module of the host through the wireless WIFI, and calculate the energy standard value. Comparing the measured value with the standard value, the error of the measured electric energy meter can be obtained.

Figure 1. Schematic diagram of installation of online calibration device at metering point at gateways

2 electric energy meter online calibration device

Figure 2. Principle diagram of online checking calibration device
The electric energy meter online verification device can be divided into a signal sampling module and a remote pulse capturing module according to functions, and the data is transmitted between the two through wireless WIFI. The system block diagram is shown in FIG. 2. The signal sampling module realizes sampling, conditioning, A/D conversion and wireless transmission of voltage and current signals under the synchronization signal provided by GPS, and provides accurate data for the remote pulse capturing module. After the remote pulse capture module receives the data, the three-phase power signal is calculated and transmitted to the pulse generation circuit in an eight-bit parallel manner, and the high-frequency square wave signal returned by the pulse generation circuit is used as a counter time base signal of the pulse capture processor to capture the measure the number of electric energy pulses of the electric energy meter (if the electric energy meter pulse is a high frequency signal, it needs to be divided), and compare the pulse numbers of the two to obtain the measurement error of the electric energy meter to be tested.

3. Hardware design

The hardware design of the power detecting device includes a signal sampling module, a remote pulse capturing module, and a GPS module and a wireless communication module.

3.1. Signal sampling module

The function of the signal sampling module is to sample, condition, AD convert and wirelessly transmit voltage and current signals.

The large voltage and current signals from the synchronization source must be converted into small voltage signals to be sent to the A/D converter. This process is called sampling. The voltage sampling circuit is first divided by a high-precision resistor and then output through a voltage follower, as shown in FIG.

![Figure 3. Voltage sampling circuit](image)

The current sampling circuit converts the large current signal into a small current signal through a high-precision current transformer, and the secondary side is connected to the IV conversion circuit to convert the current signal into a voltage signal, as shown in FIG. 4.
Figure 4. Current sampling circuit

The voltage and current sampling signals can be selected by the relay for the size range. The conditioning circuit mainly refers to the filter circuit, and the voltage signal outputted by the sampling circuit contains high-frequency noise, which is filtered by a third-order Butterworth low-pass filter. The core of the AD conversion circuit is the AD converter. The chip model is ADS8568. The chip is a successive approximation ADC chip. The performance is low power consumption and low cost. It has 8 channels to fully satisfy the synchronous conversion of 6 signals. In addition, to avoid damage when the AD converter and the microprocessor attempt to communicate, magnetic isolation is performed using the digital isolator ADUM1200.

3.2. Remote Pulse Capture Module
The processor calculates the synchronous voltage and current signals collected to obtain three-phase power, and converts them into high-frequency pulse signals through direct digital frequency synthesis technology (DDS). The power frequency conversion circuit adopts the AD9850 direct frequency synthesizer produced by AD Company, and its circuit is shown in FIG. 5. The AD9850’s control command input modes are serial and parallel. In order to perform large-scale data transmission in a short time, parallel input mode is adopted. The 2 MHz clock signal generated by the microprocessor is used as the reference frequency. Timing signals are generated by software, and RESET, FQ_UD, and W_CLK are connected to the I/O port of the processor. IOUT and IOUTB are output sinusoidal current signals that output a sinusoidal voltage signal through a resistor. QOUT and QOUTB are the high-frequency pulse output signals generated by the internal comparator. On the one hand, the high-frequency pulse is used as the time base of the processor counter, and the number of electric energy pulses of the electric energy meter is captured. On the other hand, the high-frequency low-frequency pulse is obtained after the frequency division, as a standard. Source used.
3.3. GPS timing module and data transmission module

In order to realize synchronous acquisition of voltage and current signals in different places, the time synchronization methods that can be used are network time system and GPS time system. Compared with the network, the system is more susceptible to external influences, and the GPS time system is simpler and more reliable [9-10]. The GPS Global Positioning System is a radio navigation system consisting of 18 to 24 satellites. Each satellite transmits a carrier signal of a different frequency. The receiver of the acquisition device receives carrier signals from different satellites to calculate the position and time. The timing receiver also gives a pulse signal (1 pps) per second to indicate the entire second time without accumulation error. The device adopts LEA-6T, a precise timing GPS module produced by u-blox, with a time accuracy rating of 30 ns. After using the quantization error information to compensate the time pulse interval, the accuracy can be as high as 15 ns, and the communication rate is 9600 bps. A satellite also has the ability to stabilize the output time signal, which means that the device can work normally in remote or low-visibility plant gates.

The data transmission between the signal sampling module and the remote pulse capture module relies on network port communication and WIFI. Most wireless WIFI modules use serial port and microprocessor communication, but the serial communication method is inefficient and cannot meet the requirements of high-speed real-time. So choose to convert the Ethernet data frame into a wireless channel to access the wireless local area network. This design selects the Ethernet to WIFI module HF-A11 produced by Shanghai HF Company. This module has multiple data interfaces of UART, GPIO and Ethernet. The network transmission rate is 100Mbps. Figure 6 shows the interface of the transformer network port to WIFI circuit. The simplified MAC independent interface (RMII) is used to connect the Ethernet MAC module that comes with the microprocessor to the PHY chip DP83848. The interface circuit is simple.
4. Software design

Software development can be divided into register development mode and library function development mode. In order to balance software development efficiency and program operation efficiency, the timer counting program and interrupt service program use register development mode in this design, and other time-critical programs use library functions. Development method. According to the design structure of the hardware circuit, the system programming of the power detecting device mainly includes a sampling module program and a remote pulse capturing module program, in addition to a wireless communication program.

4.1. Signal sampling module programming

The software program of the signal sampling module mainly includes the main program and the GPS second pulse external interrupt subroutine, the sampling timer interrupt subroutine and the ADS8568 read data interrupt subroutine. Figure 7 is a flow chart of the main program of signal sampling. At the beginning of the cycle of the main program, initialize the basic peripherals, sample 1024 points under the GPS synchronization signal, and then perform FFT calculation on the collected data until the data volume is sufficient. The moving average algorithm is executed when the moving average is performed, and finally the result is transmitted to the remote pulse capturing device through the wireless WIFI module.
Figure 7. Main program flow chart of signal sampling module
### 4.2. Remote pulse capture module programming

Similar to the signal sampling module, the program of the remote pulse capture module includes a main program and a subroutine. The subroutine includes: a calculation power subroutine, a power conversion into a frequency subroutine, a calculation error sub, and a host computer communication subroutine. The main function of the main program is to complete the initialization including the related configuration of AD9850. After receiving the array transmitted by the signal sampling module, complete the three-phase power calculation, then calculate the active error and the reactive error, and finally send the calculated error result to the upper computer.

After the program starts, the initialization setting is completed, the data sent by the signal sampling module is queried, the three-phase power is calculated after satisfying the new data requirement, and then according to the request sent by the host computer, the request is judged whether the calculation of the active error or the calculation of the reactive error, and then the data is The three-phase power is sent to the AD9850, converted into a high-frequency signal, and the error calculation is completed. After obtaining the request for the error of the host computer, the calculation result is sent to the upper computer. Figure 8 is a flow chart of the main program of the remote pulse capture module.

![Flow chart of the main program of the remote pulse capture module](image)

**Figure 8.** Main program flow chart of remote pulse acquisition module
4.3. Wireless communication program design

The amount of communication data between the sampling signal module and the remote pulse capture module or with the host computer is huge, and the use of Ethernet realizes the advantages of fast transmission speed and low cost. The STM32F407 comes with an Ethernet MAC module and is connected to the PHY chip through the RMII interface. The Ethernet module is set to the interrupt mode. When the data of the host computer is received, the program enters the microprocessor Ethernet interrupt. Figure 9 is a flow chart of the communication procedure between the signal sampling module and the remote pulse capture module.

![Flow chart of communication program between signal sampling module and remote pulse capture module](image)

**Figure 9.** Flow chart of communication program between signal sampling module and remote pulse capture module

5. Conclusion

This paper introduces the overall architecture and detailed design of the electric energy meter online calibration system in the electric energy meter online monitoring system, including the software and hardware design of the signal sampling module and the remote pulse receiving module. The GPS module and the wireless WIFI module are used to realize high-precision synchronization of the sampled voltage and current signals and high-speed wireless data transmission. The error accuracy of the designed electric energy metering and detecting device is better than 0.05, which satisfies the requirements of the regulations for electric energy metering and verification work. It is of great significance to reduce the comprehensive error display and analysis of the energy metering device under the actual load to reduce the workload of the on-site verification of the operation and maintenance personnel of the energy metering device. The system can provide analysis, early warning and control support to the power supply enterprise management personnel, in line with the trend of refined management.
Acknowledgments
This work was financially supported by “Science and Technology Project of China Southern Power Grid Co., Ltd.,” project fund number: CGYKJXM20170146 Fund Project.

References
[1] LONG Gui-shan, LIU Lei, LIU Ying, et al. Research on Auto-Verification and Intelligent Storage System for Smart Watt-Hour Meter . Electrical Measurement & Instrumentation, (2013)5, pp. 95 - 100.
[2] WANG Chang-rui, YI Zhong-lin, GU Shou-chen, et al. The Application and Analysis of the Running Condition Tracking and Analyzing System of Gateway Electric Energy Measurement Device. Electrical Measurement & Instrumentation, 46 (2009) 9, pp. 19 - 23.
[3] ZHANG Fan, ZHU Yongli, XIONG Haijun, WANG Dewen. Design and Realization of the Linux-Based Consolidated Monitoring Unit Prototype in Substations. Electric Power, 2014, 47 (5), pp. 150 - 154.
[4] SHEN Xin, ZHAO Danni, CAO Min. Research on energy metering device remote online monitoring and analysis platform based on internet of thing. Electrical Measurement & Instrumentation, 2015, 52 (16A), pp. 35 - 40.
[5] CHENG Ying-ying, HOU Xing-zhe, et al. Design and Realization of Condition Management System of Gateway Electrical Energy Metering Device. Electrical Measurement & Instrumentation, 2013, 50 (8), pp. 87 - 92.
[6] LU Shu-feng. The Analysis and Thoughts of Present Situation for Measurement Devices in Gateway. Electrical Measurement & Instrumentation, 2005, 42 (8), pp. 21 - 23.
[7] SHI Na, JIN Xinyu. Design of Measuring Secondary Voltage Drop Based on Distributed Synchronizing Clock. Instrument Technique and Sensor, 2008, (10), pp. 88 - 90.
[8] BiWei, Gan Yiyi, Shen Li. Distributed detecting system of electronic energy measurement based on GPS synchronizing signal source. Electrical Measurement & Instrumentation, 2016, (S1), pp. 79 - 82+87.
[9] ZHOU Wenyuan, LI Hongyun, WAN Keyou, et al. A Multi--channel Synchronous Acquisition System with GPS Timing. Computer Measurement & Control, 2015, (07), pp. 2532 - 2534.
[10] PAN Yu-ting, CHEN Yu-chen, WANG Cheng-yu, HOU Yun. Grid Frequency Measurement Research Based on GPS Timing. Chinese Journal of Power Sources, 2016, (03), pp. 709 - 710+714.