

Design of power tester for HPLC power line carrier communication module

Minqi Yu¹², Yun Tang¹², Rui Huang¹², Mouhai Liu¹² and Maotao Yang¹²

¹State Grid Hunan Electric Power Limited Company Power Supply Service Center(Metrology Center), Changsha, Hunan, 410000, China

²Hunan Province Key Laboratory of Intelligent Electrical Measurement and Application Technology, Changsha, Hunan, 410000, China

*Corresponding author's e-mail: 252066208@qq.com

Abstract. The current equipment used to test the power consumption of power line carrier communication modules not only has low dynamic power consumption, but also fails to meet the accuracy requirements for AC power tests. Based on a careful analysis of the key technologies of the dynamic power test of the communication module, this paper designs a power tester. This paper introduces the working principle of the power tester, discusses the corresponding circuit design scheme from two aspects of DC power consumption and AC power consumption, and analyzes the calculation methods of the two in detail. Finally, the test results of each test system are compared and analyzed. The power tester can achieve higher accuracy data testing.

1. Introduction

Recently, power line carrier communication technology becomes a significant part of smart grid. Electricity information collection system is required to meet AMR (remote meter reading), transformer monitoring, load control, power quality remote measurement, security monitoring, time-of-use rate (TOU), dynamic billing, and other services like power line telephones and Internet information services. At the same time, the State Grid put forward the goal of building a power consumption information collection system, namely, "fully covering power users", "fully collecting power consumption information" and "supporting comprehensive electricity price control." Traditional carrier technology cannot meet the above requirements. And HPLC technology accelerates the transmission rate of power line data and helps build the ubiquitous electric power Internet of Things^[1].

Nowadays, there are more than 600 million smart meters in China. The big number causes the power consumption of the power grid to be very large, so the power control of the HPLC module is particularly important. The dynamic power consumption and static power consumption test of the HPLC module is one of the important indicators in the technical specifications of the power user information collection system^[2].

The power consumption test of the HPLC module has two characteristics^[3]: First, the dynamic power consumption changes greatly with time. Taking a narrow-band PLC module as an example, the same data transmission time is long due to the low transmission speed. For example, using a module with BPSK modulation mode to send an application-layer packet with a length of 16 bytes takes 138 ms. For the HPLC module, due to the high transmission speed, it takes less time, and messages of the same length only take 2.97 ms. Therefore, the dynamic response of the power measuring instrument



that needs to measure the HPLC module is very high. Second, AC power consumption is very accurate. The power loss of the AC part of the PLC carrier module is relatively low, about tens of milliwatts, while the AC test part of the power meter is very accurate.

Conventional instruments are difficult to meet the two characteristics of power consumption testing, so this article designed a power consumption testing device for the above power consumption testing characteristics.

2. Principle of power tester

The hardware of the HPLC module power tester includes various modules, each module including MCU, power load, DC power test unit, AC power module, display module and network communication module. The design of the test unit for DC power consumption and AC power consumption is divided into two. The content includes the test of the meter and the concentrator module. Connect the two and use the network meter reading to test the dynamic power consumption of the device. As shown in Figure 1, the data collected by the DC power consumption unit and the AC power consumption unit are calculated by the MCU module, and the results are shown in the display module. At the same time, the PC software can also be displayed through the network communication module. Specifically, the power consumption of the HPLC module includes about two parts: one is the 12V DC power consumption and the other is 220V AC power consumption. Due to the zero crossing circuit of the module, the power consumption is mainly concentrated on DC power consumption.

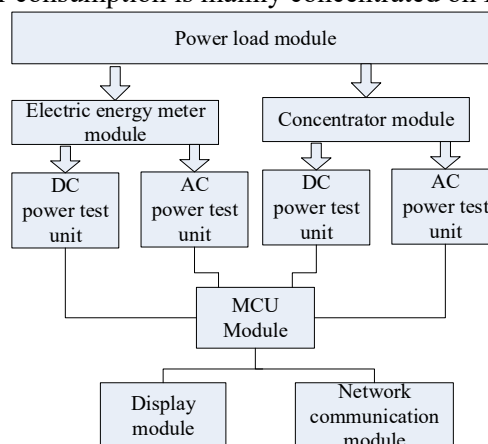


Figure1. System wiring diagram

2.1. Power load module design

Because the power consumption of the HPLC module is affected by the power line load, the power supply must be standardized, connect the power supply to the power tester, and add a line impedance stabilization network to eliminate external influences on the system. The power line load also stabilizes.

The voltages provided by the power supply are 12V, 5V, and 3.3V, respectively, after the power supply is converted, rectified, and filtered. The power supply design parameters are as follows: DC power supply design parameters are as follows: Under different loads (output current 0-0.5A), the output accuracy is better than 1%, and the voltage stability is $\leq 1\%$.

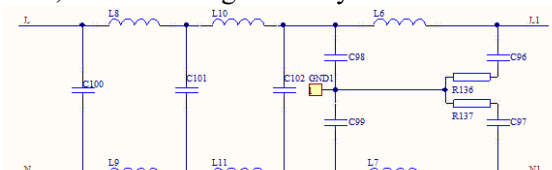


Figure2. Line impedance stabilization network

2.2. DC power test unit design

Usually, the average DC power consumption is measured by sampling the values of the instantaneous voltage u_i and the instantaneous current i_i of the N groups at equal intervals at a certain sampling rate within a certain period of time. After calculating the average value, the power P is calculated as the following formula.

$$P = \frac{1}{N} \sum_{i=1}^N u_i i_i \quad (1)$$

The instantaneous power consumption can be calculated as the product of the voltage and current acquisition values. The voltage sampling adopts the resistance voltage division method, because the power supply voltage of the HPLC module is 12V, and the ADC sampling chip exceeds the AD sampling voltage range, and its measurement range is only 3.3V. The resistor divider method uses 47K and 10K high-precision resistors to make the AD sampling voltage drop to 2.1V, which meets the sampling requirements of 3.3V. According to the current technical specifications and standards, the static current of the HPLC module is less than 100mA, the dynamic current is less than 500mA, the current sampling design is up to 500mA, and the accuracy is 1mA. As shown in Figure 3, the high-precision and low-resistance sampling resistors are first connected in series to a 12V power supply. The voltage across the sampling resistors will be compared and amplified by a precision differential operational amplifier to obtain the required voltage signal. The op amp current sampling chip used is TI's INA282. This model can achieve 50 times voltage difference across the sampling resistor. It has the following characteristics: wide common mode range -14V to 80V, offset voltage $\pm 20\mu\text{V}$, common mode suppression The ratio is 140dB, the gain error is $\pm 1.4\%$ (maximum) and gain drift (maximum) of $0.0005\% / ^\circ\text{C}$.

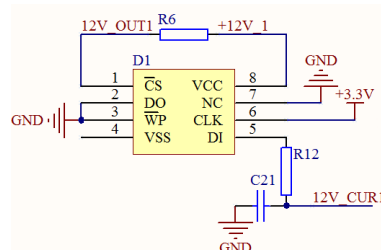


Figure3. Schematic diagram of current sampling section

2.3. AC power test unit design

Under normal circumstances, the AC power consumption of the HPLC module is mainly the power consumption of the zero-crossing circuit. The AC power consumption is calculated by voltage sampling and current sampling. The AC voltage and current sampling units are not isolated, but need to be isolated from the MCU module when transmitting data, using optocouplers and retrograde.

The AC power consumption is collected by the energy measurement chip ESEM16 of Shanghai Neusoft Carrier Microelectronics Co., Ltd. The MCU integrates a high-precision energy measurement module, including a dual 24-bit ADC for current and voltage sampling, a reference voltage source, and functions. The volume measurement has a dedicated DSP core, and the function package includes active energy, voltage and current RMS data measurement. On this basis, the average active power can also be displayed. In the dynamic range of 25°C between 1000°C , when active energy measuring, the error is less than 0.1%; in the dynamic range of 500: 1, also the measurement error of voltage and current RMS is less than 1%. The ESEM16 analog front end consists of two programmable gain amplifiers. The amplifier has current amplification on one side, gains of 1, 2, 4, 8, 16, and 32 times, and voltage sampling gains of 1, 2, 4, and 8 times. 24-bit AD sampling will be used after the PGA. High-precision voltage sampling can be completed with a precision reference voltage of 1.3V. The AC sampling circuit is shown as followed.

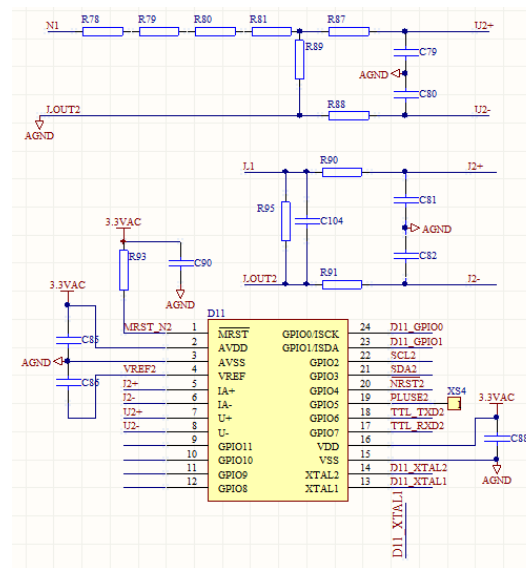


Figure 4. AC power test diagram

In the process of voltage sampling, due to the problem of measurement range, a high-precision resistor is used to divide the voltage. The module's ESEM16 voltage sampling signal is required to be controlled from 100 μ V to 500mV. According to calculations, the input signal is set to 100mV. Divided by resistance, $R_{89}=1K$ it is, $R_{81}=R_{78}=R_{80}=R_{79}=510K$. Current sampling uses a high-precision, low-resistance resistor on the power line. The ESEM16 requires a current sampling input signal of 5 μ V to 25mV. Then $P_{min}/220 \times R_{95} > 5\mu V$, $P_{max}/220 \times R_{95} < 25mV$. The power consumption at the zero-crossing circuit is particularly large, accounting for most of the AC power consumption of the entire module. Considering that the AC power consumption of modules from different manufacturers has less fluctuation, the range is set to 1mW to 300mW. Based on the above calculations, the sampling resistance is $1.1R < R_{95} < 18.3R$, and the sampling resistance is selected as 10R.

2.4. Module design of MCU

An important part of the power tester is the MCU module. MCU chose ST's STM32F207ZE, which runs at a high frequency and has an application interface. In order to meet the HPLC dynamic power test requirements, the ADC module used has a measurement accuracy of 12 bits and a sampling rate of 30 MHz.

2.5. Display module and network communication module design

The display module adopts the touch type, and the static power and dynamic power interact with the system through the interface to test. Based on the network communication module, the tester and host can interact with the test data and receive remote control, so the power tester can be integrated into other test systems through data transmission.

3. Power tester software implementation

The power tester software includes two parts, namely the ESEM16 program and the MCU program embedded in the AC acquisition chip. The data between the two is exchanged through the serial port, and the serial port connection is isolated by optocoupler. Figure 5 shows a block diagram of the test software design.

First, before the sampling process starts, the system will be initialized, and then receive test instructions from the PC or display, and the power tester system. If the received signal is to test the dynamic power consumption, the tester will start to connect to the cloud network. At this time, based on the MCU module, electricity meter and concentrator simulation, initialization of the concentrator module parameters, automatic file download and concentrator settings, the system will automatically

check the network topology according to the task, the network connection is completed, and the dynamic power consumption test process begins. If it is received to start the static power test, the previous steps will be omitted, data acquisition will be started and further analysis and processing will be started.

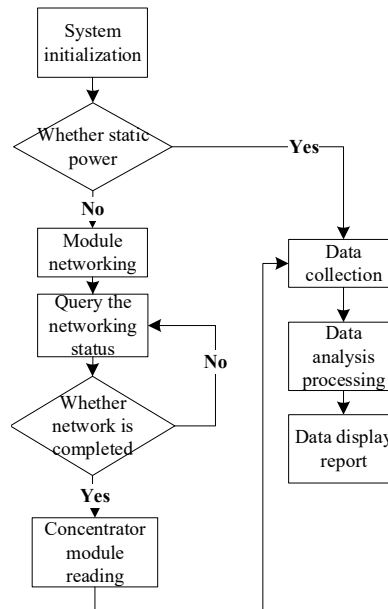


Figure5. System main program flow chart

3.1. data collection

Data collection mainly includes DC and AC voltage and DC and AC current collection. The DC voltage and current can be directly collected through the MUC module. The circuit voltage division formula can be used to calculate the current and voltage using the binary data calculation method. The DC instantaneous power consumption can be further obtained. The first round of sampling requires 100 acquisitions, and this operation must be performed for each sampling sequence. The same is true for each channel. A round of sampling requires $2 \times 10 \times 480/30000000 = 320\mu s$, and the program is used to complete the sampling. After this round of sampling is completed, the calculation time takes about 3us.

ESEM16 is the main part of the AC collection task. It can be obtained by obtaining the active power register (EM_PA) value. EM_PA is expressed in two's complement form and is a 32-bit signed number. If the sign is negative, the actual power direction is negative. The calculation process is as follows:

$$PA = \frac{DATA \times k \times V_{ref}^2}{R \times G_i \times G_u \times 2^{31}} \quad (2)$$

The decimal data of the active power register is the required DATA. After the high-precision resistor divides, k is the voltage division ratio ($k > 1$), R is the resistance of the shunt (in Ω), and G_i and G_u are current and voltage The channel PGA gain V_{ref} is the ADC reference voltage ($V_{ref} = 1.3V$). After the AC collects the task, the MCU module will receive the test data and listen to the serial port DC.

3.2. Data analysis and processing

In the static power test, through the error data filtering program, each data in each sampling sequence will be filtered to reduce the possibility of data errors and improve efficiency in later applications.

This limit average filtering algorithm reduces randomness. The data pulse interference caused by factors can eliminate the occasional noise in the power system in a large area..

The test data of the HPLC module includes dynamic power consumption data and static power consumption data, and the transmission speed is very fast. However, the static power consumption is not the same as the dynamic power consumption data filtering. The dynamic power consumption test data is shown in Figure 6, and the threshold $P_{threshold}$ is set. When the dynamic power test data is greater than this threshold, the dynamic power consumption is determined. When it is smaller than this threshold, it is determined as static power consumption, because the static power consumption of the module is much smaller than the dynamic power consumption. Data filtering must be processed after obtaining multiple sets of dynamic power consumption data, so as to reduce the impact of accidental noise in the power system on the results and improve the reliability of the test.

$$p = \begin{cases} p_{dynamic} & (|p| > p_{threshold}) \\ p_{static} & (|p| < p_{threshold}) \end{cases} \quad (3)$$

The accuracy of the components will affect the overall accuracy of the power tester, and the accuracy of the test data will decrease. Therefore, an additional power compensation calibration mechanism needs to be added. The method adopted is to add a fixed loss value ΔP to the test result for power compensation calibration.

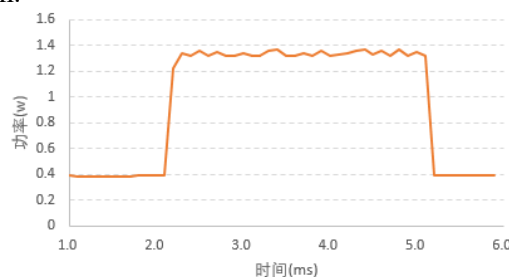


Figure6. Dynamic power measurement data

3.3. Data display and remote control

The display module can convert the display operation into a serial command, and use the serial port to communicate with the MCU module to complete the test of the control power tester. At the same time, the test results will also be transmitted to the display module through the MCU module, so that the test results can be obtained.

The remote control of the power tester is to communicate with the host remote network through TCP / IP protocol, and the hardware is through the network communication module. The application layer protocol used is a custom protocol with the function of automatic CRC check of the data in it. Guaranteed data security and stability.

4. Comparison and analysis of measurement results

To further verify the accuracy and practicability of the power tester, a variety of test methods were used to compare the static and dynamic power consumption of the HPLC module of the meter. To ensure the integrity of the experiment, ten communication modules were randomly selected for power consumption testing. The results are shown in Table 1.

Analyzing the above table, although the results obtained under different measurement methods tend to be consistent, specific dynamic power measurement results are still written differently. The dynamic power tester is consistent with the test results of the provincial network measurement center. In this respect, the results of the power tester show a large inconsistency. Depending on the comparison with the transmission speed of the HPLC module, its dynamic response is slow and the power consumption changes are also slow.

Table 1. Comparison of measurement results

Testing method	Static power (W)	Dynamic power (W)
A provincial metrology center	0.391	1.351
A power measurement result	0.395	1.034
Power tester results	0.389	1.343

5. Conclusion

This paper designs a HPLC power tester, which includes multiple modules, including a DC power test unit, MCU module, AC power module, power load module, network communication module and display module. In order to ensure precision and accuracy, a high sampling rate ADC chip and a high-precision AC power measurement chip are used, which have the ability to quickly achieve a DC power measurement response, and the AC power measurement accuracy is also high. The verification results prove that the dynamic power consumption of the power tester is more accurate. Due to the low cost of the equipment, the cost is lower and it is more meaningful to promote.

The power test instrument designed in this paper has low cost, high integration, fast dynamic response, and accurate power test. Provides a method and equipment for the measurement profession to accurately measure the power consumption of the HPLC module. This new method can be widely used in provincial metrology centers.

Acknowledgments

This work was supported by the State Grid Headquarters Project (No. 5216A019000S).

References

- [1] Li Shihong, Schmitz Alexander, Lee Hsiaoju, Mach Robert H. Automation of the Radiosynthesis of Six Different ¹⁸F-labeled radiotracers on the AllinOne.[J]. EJNMMI radiopharmacy and chemistry, 2017, 1(1).
- [2] Dong, Michael W. HPLC Systems and Modules Introduced at Pittcon 2013: A Brief Review[J]. LC GC North America, 2013, 31(4).
- [3] M. Shukri Hapeez, M. I. Mohd Yassin and M. Kamal Hamzah, "Storage of online HPLC data for pharmaceutical research applications using XML database," 2010 5th IEEE Conference on Industrial Electronics and Applications, Taichung, 2010, pp. 1605-1609.
- [4] Engineering - Power Engineering; New Power Engineering Findings from Wayne State University Discussed (Experimental Validation of a Three-Component Surrogate for Sasol-Isoparaaffinic Kerosene in Single Cylinder Diesel Engine and Ignition Quality Tester)[J]. Energy Weekly News, 2018.
- [5] Longtao Hu, Tiansuo Fan, Dongguang Zuo, Ding Yuan, Fengchen Li. A Design of Power Supply Circuit Module of Fuse General Tester[P]. Proceedings of the 2016 6th International Conference on Machinery, Materials, Environment, Biotechnology and Computer, 2016.
- [6] Xiaoquan Li, Zheng Liu, Tao Pu. Electrical Performance Tester for a Double Frequency Unit of a Power supply Vehicle[P]. Proceedings of the 2nd International Forum on Management, Education and Information Technology Application (IFMEITA 2017), 2018.
- [7] Jianshi Bai, Tong Wu, Fang Shen, Yi Liang, Jing Gao, Zhentao Han. A Novel Design of Analog Signal Power Amplifier Module for Relay Protection Tester[P]. Proceedings of the 2017 5th International Conference on Machinery, Materials and Computing Technology (ICMMCT 2017), 2017.