25th IMEKO TC4 International Symposium
23rd International Workshop on ADC and DAC Modelling and Testing
IMEKO TC-4 2022
Brescia, Italy / September 12-14, 2022

Design of integrated multi-user electric energy meter

Jianbo Liu,Wenqiang Li, Mei Yang, Xiao Liu,Bin Deng,Weizhao Wang, Xuefeng Ma

Shandong Engineering Research Center of Reliability Evaluation for Electric Energy Metering Devices，Shandong Institute of Metrology, No.28, Qianfoshan East Road, 250014 Jinan, China
18553159166@163.com

Abstract **–In this paper, an integrated multi-user energy meter was designed, which achieves accurate measurement of multi-user energy through circuit sharing and current sampling respectively. The integrated design has the advantages of small size, low cost, easy installation and use, and easy implementation of remote data transmission and intelligent control.**

Keywords **–Multi-user electric energy meter, energy measurement, integrated design**

I. INTRODUCTION

With the development of electronic technology, static electric energy meters have emerged and been widely used for their advantages such as high accuracy, good stability, and remote data transmission [1-3]. Single-phase static electric energy meters are mainly used for electric energy measurement of residential users. Due to the slow change of power load of residential users, the voltage of all users in each distribution unit is the same. The difference is the current flowing through each user's circuit. The voltage sampling circuit sharing and multi-channel cyclic sampling mode of current circuit are adopted to integrate multiple meters of electric energy meter and realize multi-user electric energy measurement[4-10]. Based on this, an integrated multi-user electric energy meter that can realize multi-channel electric energy measurement was designed, The electric energy meter circularly switches the current signal of each user's loop through the electronic switch with a switching time of less than 1ms, so as to sample the current signal of all users. Multi-user electric energy meter has the characteristics of small volume, low cost and convenient installation and use. Experiments show that the multi-user electric energy meter meets the requirements of IEC 62053. At present, it has been widely used in school, mine and other occasions.

II. PRINCIPLE AND STRUCTURE OF MULTI-USER ENERGY METER

The voltage sampling of the conventional static energy meter uses a voltage transformer to convert a large voltage to a small voltage, and the current sampling uses a micro current transformer to convert a large current to a mA-level small current, and then uses a precision resistor to convert the small current to a small voltage. The two signals directly enter the metering chip to accumulate energy by integration, and achieve accurate energy measurement by calibration.

The multi-user energy meter adopts the same working principle. Due to the slow change of the electricity load of the resident users, the energy measurement of multiple users together is collected, the voltage sampling loop is shared, and the current sampling loop of multiple users is independent, and the current sampling signal is connected to the metering chip through an electronic switch. The principle of the multi-user energy meter is shown in *Figure 1*.

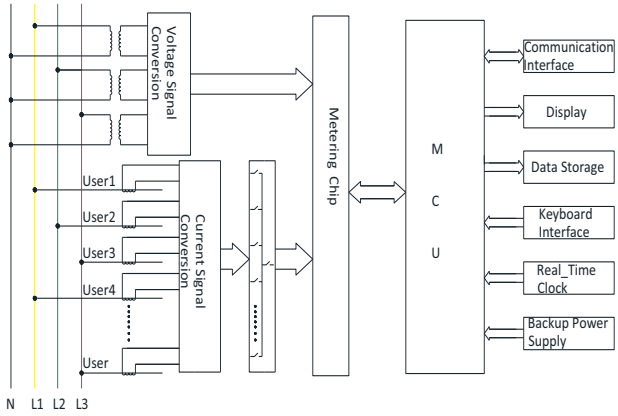

Fig. 1. The principle of the multi-user energy meter.

In the figure above: three voltage transformers are used to collect the voltage signal of the power supply circuit. The current signal output by the current transformer of each user circuit is connected to the signal filter board, and then connected to the metering board together with the voltage signal after filtering. The metering chip on the metering board multiplies the voltage signal and current signal to obtain the power data. The main control CPU reads the power data of each household and multiplies the time data to realize the transformation to the electric

energy signal.

Because the current signal in the user circuit cannot change suddenly, the current signal of the user circuit is obtained by interval acquisition, and then the user current data in the sampling interval is restored by general statistical method. In this way, the obtained user current data can accurately reflect the real data of the user. Three households are switched every 1 second. The average acquisition cycle of each household is 330ms.

Voltage Signal Conversion—Use a voltage transformer to convert a large voltage into a small voltage that can be directly input to the chip; Current Signal Conversion—Use current transformer to convert large current into small current; Metering Chip—Processor for accumulating electric energy through two input signals; MCU—Micro Control Unit; Communication Interface—Interface for transmitting instructions and data.

The household-by-house circulation method belongs to intermittent collection, and the collection speed must be fast to meet the energy measurement requirements. According to Shannon's sampling theorem, the sampling interval of 50Hz (period 20ms) should be less than 10ms. Taking into account the influence of harmonics, the sampling interval is generally not more than 4ms. For multi-user energy meters of 24 households, the sampling interval should not be less than 1/6ms.

The CS5460 sampling chip is used, its conversion frequency is F=MCLK/1024, MCLK is the frequency of the external crystal oscillator, if MCLK=12MHz, then F=11719Hz, that is, the time to complete an acquisition is about 1/12 ms, which is less than 1/6 ms and fully meet the requirements.

The ac energy measurement is realized by measuring the power along with the integral of the time. A high speed Analog to Digital Converter (ADC) in the measurement and processing unit is used for the synchronous sampling of two voltage and current sampling signals. The micro-processing unit computes the energy according to the discrete digital signals. The calculation of the energy is get from equation as follow.

$$W = \frac{1}{T}\sum_{k=1}^{N} u(k) \times i(k) \qquad (1)$$

$$T = N \times \Delta t$$

Where T is the time interval of the sampling, N is the integer sequence.

Phase lock technology is applied to lock the sampling frequency automatically with the multiple of the frequency of the input signals. With this phase lock, the influence for the measurement caused from the drift of the clock signal is eventually avoided [11].

The continuous cyclic switching of the multi-channel current sampling signal through the electronic switch realizes the simultaneous measurement of multi-user electrical energy.

For multi-user energy meters with a large number of users, three-phase four-wire power supply is generally used. Each of the three phases of L1, L2, L3 has an independent metering unit. L1-phase supplies power to No.1, 4 , 7 households, L2-phase supplies power to No.2, 5 , 8 households, and L3-phase supplies power to No.3, 6 , 9 households, etc., multi-user energy meter can realize the energy measurement of 24 households or more. The internal structure of the multi-user energy meter is shown in *Figure 2*.

Fig. 2. Internal structure of multi-user electric energy meter.

III. ENERGY MEASUREMENT ERROR

Due to the multi-cycle sampling mode, the sampling frequency of each household is reduced exponentially compared to the conventional static energy meter, which will affect the accuracy of energy measurement.

In order to verify the accuracy of energy measurement, taking the first 6 households of a multi-user energy meter with a type of 200V , 5 (50) A as an example, according to the requirements of IEC 62053, the energy error of multi-user energy meters of each household at a load current of 0.5A, 5A and 50A and a power factor of 1.0, 0.5L and 0.8C, is measured, respectively [12].

In the experiment, a verification equipment was used, for AC electical energy meters to measure the energy error. Its measurement range is 220 V, (0.1~100) A, and the uncertainty of energy measurement is 0.05% (k = 2). The measurement results are shown in Table 1.

Obtained from Table 1, the maximum error of energy measurement in the first 6 households of multi-user energy meters is -0.34%, which meets the requirements of resident users for level 2 meters. Although the multi-channel cyclic sampling mode reduces the sampling frequency of each household, the multi-user energy meter can still meet the energy measurement needs of

residential users.

Table 1. Energy measurement error of multi-user energy meters.

user	load point	Error (%)		
		cosϕ=1.0	cosϕ=0.5L	cosϕ=0.8C
1	220 V 0.5 A	- 0.22	- 0.13	- 0.14
	220 V 5 A	- 0.23	- 0.11	- 0.12
	220 V 50 A	- 0.19	- 0.15	- 0.17
2	220 V 0.5 A	- 0.23	- 0.23	- 0.21
	220 V 5 A	- 0.16	- 0.19	- 0.17
	220 V 50 A	- 0.21	- 0.24	- 0.23
3	220 V 0.5 A	- 0.22	- 0.34	- 0.22
	220 V 5 A	- 0.20	- 0.30	- 0.14
	220 V 50 A	- 0.15	- 0.17	- 0.18
4	220 V 0.5 A	- 0.21	- 0.28	- 0.23
	220 V 5 A	- 0.18	- 0.13	- 0.16
	220 V 50 A	- 0.21	- 0.16	- 0.15
5	220 V 0.5 A	0.32	0.29	0.28
	220 V 5 A	0.31	0.23	0.26
	220 V 50 A	0.32	0.31	0.33
6	220 V 0.5 A	- 0.23	- 0.28	- 0.07
	220 V 5 A	- 0.11	- 0.10	0.06
	220 V 50 A	- 0.18	- 0.20	0.08

Due to the use of integrated design and circuit sharing technology, compared with conventional static energy meters, the volume of multi-user energy meters is greatly reduced, the cost is also greatly reduced, at the same time it is easy to install and maintain, and has broad application prospects.

IV. OTHER FUNCTIONS

Due to the use of micro-processing technology, multi-user energy meters can achieve multiple functions. It can realize the functions of prepaid use of electric energy, remaining power alarm, and power failure due to arrears by the prepayment function module, the functions of multi-rate by the clock module, the remote load switch can be opened or closed by the control module, and remote data transmission can be realized by the communication module, memory can realize power storage and query of multiple users. The schematic diagram of the functional structure of the multi-user energy meter is shown in *Figure 3*.

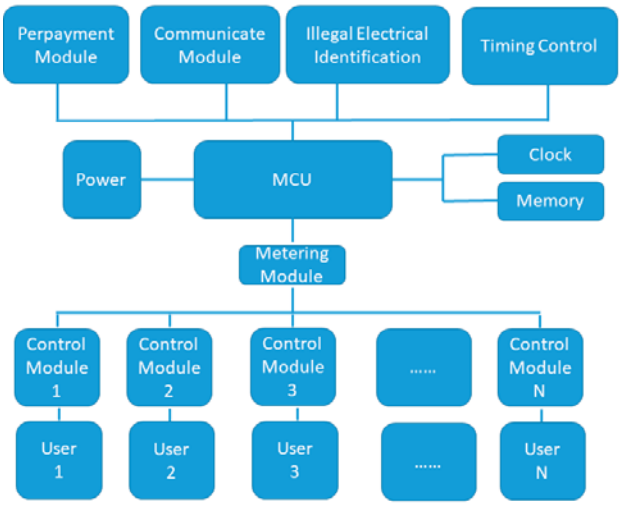

Fig. 3. The schematic diagram of the functional structure of the multi-user energy meter.

V. CONCLUSIONS

In this paper, based on the characteristics of the slow changes in the electricity load of residential users, an integrated multi-user energy meter have been designed, which uses independent sampling of the current loop and sharing with other circuits, which greatly reduces the size and cost of the energy meter and is easy to install and maintain. After actual measurement, the energy measurement error of the multi-user energy meter fully meets the needs of the residents. Due to the use of micro-processing technology, multi-user energy meters can achieve the advantages of prepayment, multiple rates, remote control of load switches, multi-channel data storage, remote data transmission, etc., and have a broad application prospect.

VI. ACKNOWLEDGMENT

During the research, we received the guidance and help from Professor Cao Ruiji of SDIM China. Under the guidance, we have realized the integrated design by circuit sharing technology. We would like to express my admiration and heartfelt thanks to Professor Cao. During this process, we also got the guidance of Dr. Wang Lei of NIM China, and I would like to express our gratitude to Dr. Wang.

REFERENCES

[1] R.F Masnicki, "Some Remarks on the Accuracy of Energy Meters," 2018 IEEE International Conference on Environment and Electrical Engineering and 2018 IEEE Industrial and Commercial Power Systems Europe (EEEIC / I&CPS Europe), Palermo, 2018, pp. 1-5.

[2] A. Cataliotti, V. Cosentino and S. Nuccio, "The metrological characterization of the static meters for

reactive energy in the presence of harmonic distortion" 2007 IEEE Instrumentation & Measurement Technology Conference IMTC 2007, Warsaw, 2007, pp. 1-6.

[3] A. Bernieri, G. Betta, L. Ferrigno and M. Laracca, "Electrical energy metering in compliance with recent european standards," 2012 IEEE International Instrumentation and Measurement Technology Conference Proceedings, Graz, 2012, pp. 1541-1545.

[4] Hu Chang-lun, Wang Xiao-jun, Ma Li-guo, Zuo Ya-nan. Development of Multi-users Multi-function Watt-hour Meter Based on ATT7022B[J]. Electronics Quality, 2014, (2): 21-26 .

[5] GONG Maofa, ZHANG Xuebin, LIU Qingxue, GONG Zheng, WANG Yongqing. Multi-user and multi-functional prepayment meter based on CS5460A [J]. Electric Power Automation Equipment, 2011, 31(9): 121-124.

[6] TANG Qiufang, LUO Meilin, ZHOU Shaowu, ZHOU Minghui. Multi-users Watt-hour Intellectual Meter Based on ARM[J]. MODERN ELECTRONICS TECHNIQUE, 2009, 32(6): 158-161.

[7] TANG Yuan-xin, HE Liang, SUN Zhai-qing, ZENG Yi-qing. The multiuser central electrical energy meter and its selection[J]. CHINA HOUSING FACILITIES, 2006,(4): 45-47.

[8] JI You, TANG Yuan-xin, GONG Mao-fa, GONG Zheng, HUANG He-song. Power Consumption, Functions and Features of Multi User Smart Watt-hour Meter[J]. Science & Technology Information, 2014, (3): 66,89.

[9] YANG Mei, CAO Rui-ji. The Design Features and Causes Interference of Multi-users Electromechanical eter[J]. ELECTRICAL MEASUREMENT & INSTRUMENTATION, 2010, 47(Z2): 95-98.

[10] JIANG Ji Shun. Design of a novelty multi-user single-phase watt-hour meter[J]. MICROCOMPUTER & ITS APPLICATIONS, 2009, 28(11): 77-79.

[11] X. Ma, W. Li, G. Yu, R. Cao, Q. Zhang and X. Zhang, "Development of high voltage ac energy meter," 2012 Conference on Precision electromagnetic Measurements, Washington, DC, 2012, pp. 132-133.IEC 62053-21:2003 Electricity metering equipment(a.c.) - Particular requirements - Part 21: Static meters for active energy(classes 1 and 2).