An On-line Multiplexed High Accuracy Electric Energy Meter Based on Dual-access RAM

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Abstract. The accuracy of electric energy meter is important for power consumers and power enterprises. Therefore, the work is dedicated to the development of an on-line multiplexed high accuracy electric energy meter. The accuracy of electric energy meter and the power quality can be monitored in real time. In order to enhance the performance of signal process, dual-access RAM is employed to link the double DSP which realize data acquisition and data process separately. And the multi-channel is designed to meet the demands of gateway meter. Besides, half-full mechanism of dual-access RAM is designed to coordinate the double DSP. Moreover， the tests of the system with balanced load and unbalanced load have been carried out individually. The standard electric energy meter is proved with the accuracy of 0.05%.

1 Introduction

Electric energy meter must be calibrated periodically in order to ensure the accuracy of power metering, which is closely related with power generation enterprises and power consumer. At present, researches about the on-line monitoring technology of electric energy metering device have been performed[1-2]. However, the power quality is becoming poor with the application of more and more on-linear devices and power electronics devices[3-4]. So, the on-line calibrating electric energy meter and monitoring power quality is quit important. However, power quality analysis and electric energy meter calibration can't be realized in one on-line instrument[5-7].

To develop an on-line multiplexed high accuracy electric energy meter, there are four keys considerations.

--Multi-channel calibration for electric energy meter: monitoring multi-meter is designed to meet the demand of site calibration. And short-circuit and open-circuit is not permitted respectively in alternation of circuit of current and voltage in order to ensure the reliability of the system.

--Real-time calibration of electric energy meter and harmonics analysis: double DSP is designed, which realize data acquisition and data process respectively.

--Coordination of double DSP: Dual-access RAM play the role of a bridge for double DSP. And half-full mechanism of RAM is proposed to coordinate the double DSP.

According to the considerations listed above, an On-line Multiplexed High Accuracy Electric Energy Meter has been developed. Real-time calibration of electric energy meter and power quality analysis can be realized simultaneously.

2 Power Meter Calibration Principle

Comparative method is usually employed for calibrating electric energy meter between the tested subject and the standard electric energy meter. And the calibration method has been illustrated in JJG596-2012 Electrical Meters for Measuring Alternating-current Electrical Energy[8]. The calibration principle of electric energy meter is shown in Figure 1. The same signal is fed to the tested subject and the standard electric energy meter. Then, the values of power metering by the tested subject and the standard electric energy meter is compared to achieve the error of the tested electric energy meter[9].

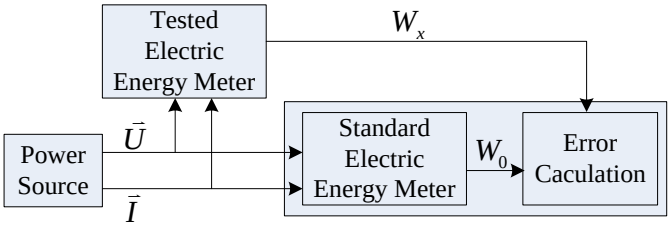

Figure 1. Calibration diagram of electric energy meter

Supposing the power metering values of the tested electric energy meter and the standard one is W_x and W_0 respectively, the error γ of the tested subject can be expressed as the following.

$$\gamma = \frac{W_x - W_0}{W_0} \times 100$$

3 Instrumentation

Instrumentation Structure. The proposed instrumentation mainly includes multi-channel module, data acquisition module, CPLD, DSP(1), dual-access RAM, DSP(2), PLL and so on. Figure 2 reported the structure of the instrumentation which can calibrate electric energy meter and analyze power quality in real-time. Double DSP is the core of the proposed instrumentation. Dual-access is the bridge between the double DSP to realize data acquisition and signal analysis in the different DSP which respectively are DSP(1) and DSP(2). The signals from tested electric energy meters are fed to data acquisition module via multi-channel module. The output of data acquisition module is provided for DSP(1). And DSP(2) read data in dual-access RAM to analyze signal. At the same time, the results about calibration and quality analysis can be communicated to remote PC server which can control the period of calibration. Besides, the interface of pulse output for calibration is designed to ensure the instrument accuracy.

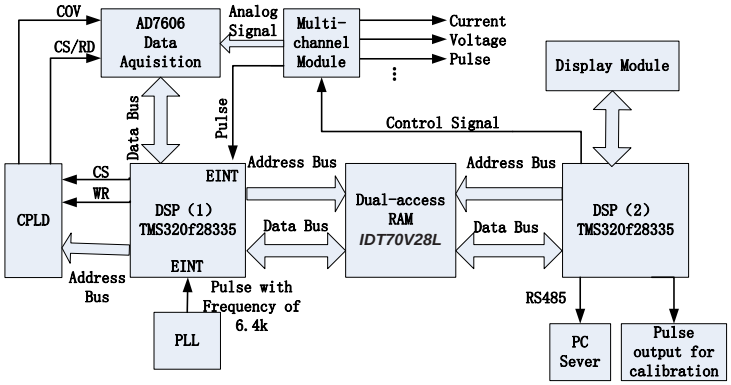

Figure 2. Instrumentation Structure

Multi-channel Calibration for Electric Energy Meter. In order to meet the demand of site calibration, multi-channel polling mechanism is designed. And short-circuit and open-circuit is not permitted respectively in alternation of circuit of current and voltage in order to ensure the reliability of the system.

Figure 3 gives the principle of multi-channel polling for current signal. I-V conversion module is designed, which can convert current signal to voltage signal and can prohibit open-circuit in current circuit in multi-channel polling of the tested electric energy meter. Besides, the signal will be provided for decoding module via the preprocess module in order to ensure only one tested electric energy meter be calibrated.

Multi-channel polling for voltage signal is shown in Figure 4. Relay is used to switch channel of calibration. Interlocked operation mechanism is proposed to prevent interfere with each other in multi-channel polling. And the short-circuit in voltage circuit will not appear in case of malfunction of any rely. Furthermore, in consideration of arc caused by switching AC signal in voltage circuit which has important influence on the reliability of delays and the accuracy of calibrating electric energy meter, the switch of low signal is designed via transformer module to increase the reliability of multi-channel polling.

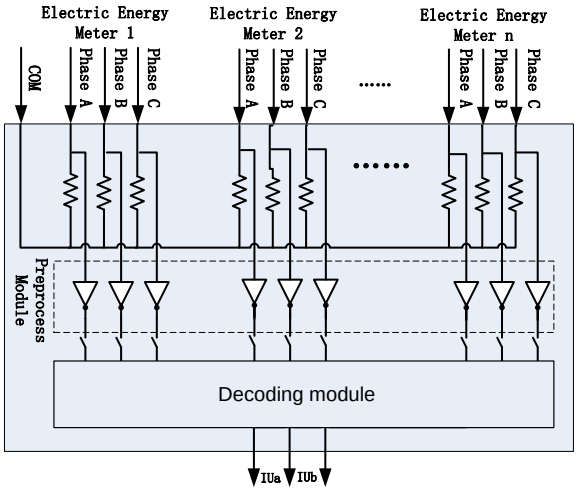

Figure 3. Multi-channel polling for current signal

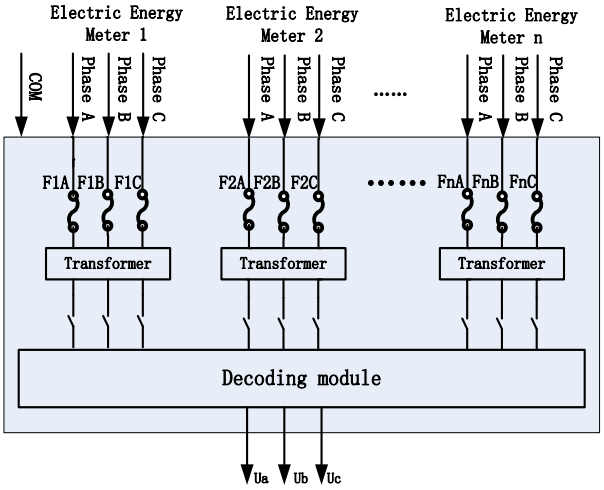

Figure 4. Multi-channel polling for voltage signal

Coordination of double DSP. Double DSP are proposed in order to calibrate electric energy meter and analyze power quality analysis in real-time. Data are acquired in DSP(1) which transmit raw data to dual-access RAM. And DSP(2) read data from dual-access RAM to calculate error of electric energy meter and indexes of power quality[10].

One dual-access RAM chip of 64kByte is designed in the instrument, which is assigned as signal storage area and flag bit area in Figure 5. the floats of three-phase current and voltage is stored in signal storage area, which occupy the area of 10kByte respectively. The sampling points in one period is 128. So, three-phase signal in 20 periods can be stored. And flag bit area is used to store half-full flag, full flag, start flag and stop flag of calibrating electric energy meter.

DSP(1) is trigged by the pulse of the tested electric energy meter to acquire data which is stored in dual-access RAM. At the same time, the address pointer of dual-access RAM is added automatically. And the data in signal storage area is stored circularly. When the signal storage area is half-full or full, the half-full flag or full flag is set to trig DSPB to read data from the corresponding signal storage area.

4. Result and Discussion

According to JJG1085-2013 Reference Meters of Electrical Energy[11], the tests of the proposed device with balanced load and unbalanced load have been carried out individually. Besides, the voltage is 100V, and the current is 5A during the tests with four-wire three-phase system.

For balanced load tests, the error tests are designed with different power factors. Among the tests, the error tests with power factor of 1 are carried out in the current range of 0.05Ib to Ib with power factor of 1, and the error tests with the other power factors are also carried out in the current range of 0.1Ib to Ib. the error and standard deviation achieved in error tests with balanced load and 0.05Ib-Ib

current are illustrated in Figure 5 and Figure 6. and the standard deviations are achieved via 5 test results. It can be found that the error of the proposed device is decreasing with the test current increase from Figure 7. Besides, the phenomenon is showed in Figure 5 and Figure 6 that the standard deviation of the device with different power factors is also decreasing with the test current increase. In other words, the error of the proposed device is more and more steady with the test current increasing. Furthermore, the maximum standard deviation in the tests with power factor of 1.0 and 0.5L, and current of 0.5Ib to Ib is 0.00233%, which is lower 0.005%.

For unbalanced load tests, the error tests are designed with power factor of 1.0 and 0.5L, and current range of 0.2Ib to 1.2Ib. The error variance characteristics with unbalanced load are reported in Figure 7. It can be found that the absolute value of the device error is decreasing with the test current increase. In addition, the error value of the device with power factor of 0.5L is higher than that with power factor of 1.0 during the tests of unbalanced load, which is correspondence with the error tendency in JJG1085-2013 Reference Meters of Electrical Energy.

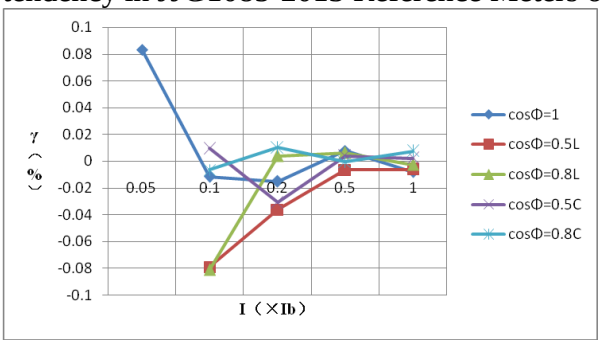

Figure 5. Error characteristic of power meter with balanced load

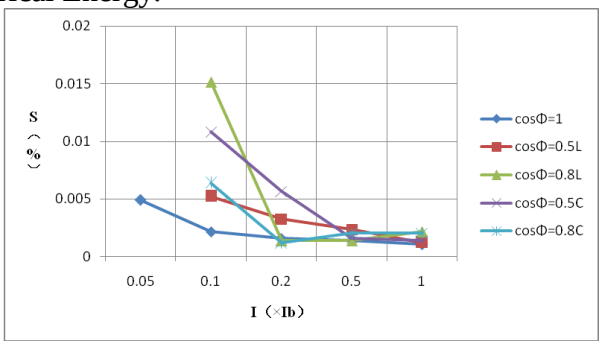

Figure 6. Standard deviation of power meter error with balanced load

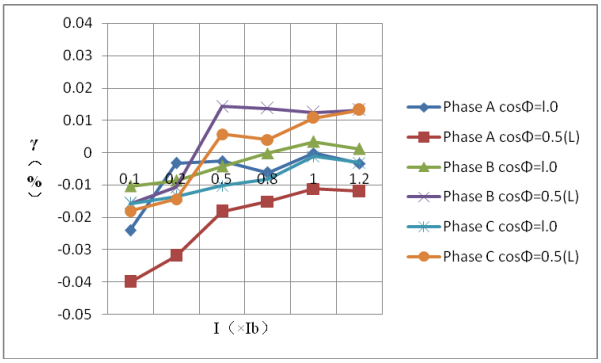

Figure 7. Error characteristic of power meter with unbalanced load

Figure 8. On-line monitoring results

Above all, the error of the proposed device is higher and unstabler in low current than that in high current, which is caused by the interfered low current. And the proposed device is proved that the accuracy of the device is better than 0.05%. Besides, the proposed device has been applied in Chaozhou transformer substation in china. The on-line monitoring results are shown in Figure 8.

5 Conclusions

In order to meet the demand of monitoring power quality and calibrating electric energy meter, a multiplexed high accuracy electric energy meter based on dual-access RAM has been developed with multifunction, including on-line verifying of electric energy meter, power quality real-time analysis and fault diagnosis. Dual-DSP and dual-access RAM are employed in the system to ensure the real-time of signal acquisition and data analysis. And multi-channel calibration for electric energy meter is proposed in consideration of the reliability of multi-channel polling for current signal and voltage signal. In addition, half-full trigger mechanism of dual-access RAM is designed to implement signal acquisition and data analysis synchronously through dual DSP. In order to increase the accuracy of the system, phase-locked loop(PLL) is designed.

The tests of the proposed device with balanced load and unbalanced load have been carried out individually. The new reference electric energy meter is proved with the accuracy of 0.05%. Furthermore, the proposed device has been applied successfully in Chaozhou transformer substation in china.

Acknowledgment

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