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THE DESIGN OF ENERGY-EFFICIENT MONITORING TERMINALFOR POWER SUPPLY AND DISTRIBUTION SYSTEM OF ENTERPRISE BASED ON STM32

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ABSTRACT

The significance of energy-efficient monitoring for power supply and distribution system lies in guiding enterprise to implement energy-efficient reconstruction, reducing energy consumption, and alleviating energy supply and construction pressure. According to the standard GB/T16664-1996 of People's Republic of China, daily load factor, load coefficient of transformer and line cost rate need to be monitored. For this reason, an energy-efficient monitoring terminal system based on Coretex-M3 STM32F103 was presented in this paper, the system architecture, software flow chart was also provided, and the core circuit was described. The terminal system, presented in this paper, has some superiority of fully function, simple structure, easy to use and high accuracy, and has a broad market prospect.

Keywords: *Energy-Efficient Monitoring, On-Line Monitoring, STM32.*

1. INTRODUCTION

Energy-efficient and consumption reducing are the main ways to improve economic benefit and market competitiveness for enterprises. So it is important to provide accurate and reliable monitoring data for energy-efficient and consumption reducing of enterprises through energy-efficient monitoring method, help enterprises to find the direction of energy-efficient and establish the technical renovation measures. When the previous energy-efficient monitoring instruments are in operation, the voltmeter, ammeter, dry battery and phase meter are needed, so it is not very convenient to use, in the mean time, test date needs manual record, the test and analysis are not synchronously, all of this will aggravate analysis error. So, a high accuracy, briefness and portable on-line testing device is desperately needed.

At present, such existing testing devices are mainly based on SCM, DSP and ARM. But, there are some shortcomings in measurement accuracy and structure complexity in those based on SCM, and some shortcomings in cost and embedded extent in those based on universal DSP, the special DSP has relatively fixed function, and provides relatively smaller space for system design and testing device manufacturer. As to the existing testing devices based on ARM, the applicable ARM7 TDMI has insufficient peripheral resource and the higher end ARM9 has the higher complexity and higher cost. So, one low-cost microprocessor that meets the requirements becomes the key factor for energy-efficient monitoring devices.

The high-performance, low-cost and low-power consumption STM32 based on Cortex-m3 kernel from ST Microelectronics provides a good opportunity and broad space for energy-efficient monitoring terminal design. Cortex-M3 is a 32 bit microprocessor core with 32 bit internal data path, 32 bit register and memory interface, and it has the Harvard structure, independent instruction bus and data bus, and has the ability of fetching instruction and data at the same time, thus, it has greatly increased the operation performance.

In section 2 of this paper, the structure diagram of measuring terminal is discussed, the main hard ware of the terminal are discussed in section 3, the main software design is introduced in section 4, section 5 and section 6 give the testing result and conclusion.

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2. ENERGY-EFFICIENT MONITORING SYSTEM OVERALL STRUCTURE AND THE MONITORING TERMINAL HARDWARE STRUCTURE

2.1 The Overall Structure of Energy-efficient Monitoring System

In order to meet the requirements of Chinese GB/T16664-1996, daily load factor and load coefficient of transformer, line cost rate and power factor of enterprise power system need to be monitored. The energy-efficient monitoring system comprises upper computer, N transformer monitoring terminals and communication bus, the structure diagram as shown in figure 1.

The monitoring terminal transmits detected data, such as maximum load and average load of transformer power system, voltage, current and power of transformer, and sent them to computer, the daily load factor, load coefficient, line loss rate and the power factor of power system was calculated by computer to realize energy-efficient

monitoring. The calculation method of the above

parameters can be found in the GB/T16664—1996 .

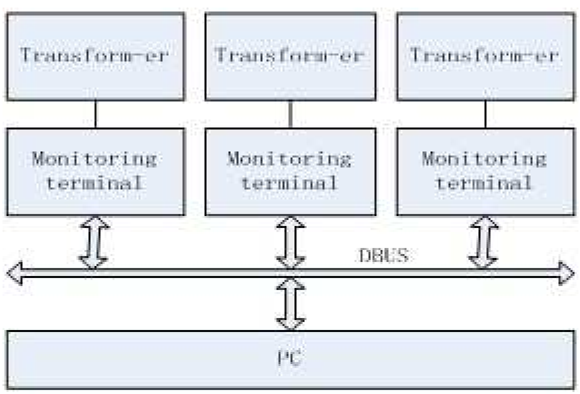

Figure1 Block Diagram Of Overall System

2.2 The Hardware Structure of Monitoring Terminal System and Its Working Principle

To meet the parameters measurement requirements, the on-line detection system of transformer actual load comprised controller minimum system circuit, sampling circuit, A/D conversion circuit and power circuit, the overall structure diagram as shown in figure 2.

In this system, three phase voltage and current sampled signal was sent to six channel 16 bit ADC-AD7656-1, and the processor adopted STM32F103. A phase voltage signal was changed into rectangular wave use waveform transformation circuit, and then the phase lock circuit was adopted to double the frequency, the rectangular signal from phase lock circuit as the external interrupt signal of STM32F103 to control ADC. So that AD76546-1 can uniformly-spaced sample N date from voltage and current signal in one cycle, these date were processed by STM32F103 to get the needed RMS voltage, RMS current, active power, reactive power and power factor, and all of those processed date will be stored and sent to upper computer at the regulation time according to Chinese GB/ T16664—1996.

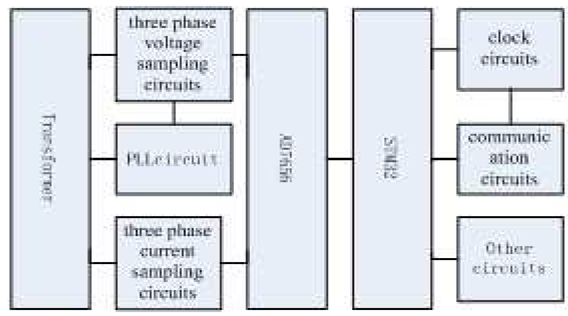

Figure2 Structure Diagram Of Measuring Terminal

3. DESIGN OF HARDWARE CIRCUIT

3.1 Design of Sampling Circuit

The sampling circuit includes voltage sampling circuits and current sampling circuits as respectively shown in figure 3 and figure 4.

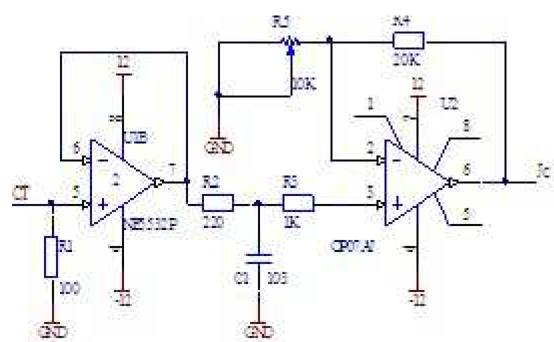

Figure.3 Three Phase Voltage Sampling Circuit

In figure 3, CT is split core type current transformer, its output signals were sent to voltage follower and non-inverting amplifier after being transformed into voltage signal to match the best working state of A/D converters.

In figure 4, the measured voltage signals were divided into two-channel signal after attenuator circuits. One of them was sent to non-inverting amplifier to match the best working state of A/D

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converter, and the other was transformed into rectangular wave by comparator and was sent to PLL circuit to obtain N times frequency signal which determines the number of samples in one AC electrical cycle.

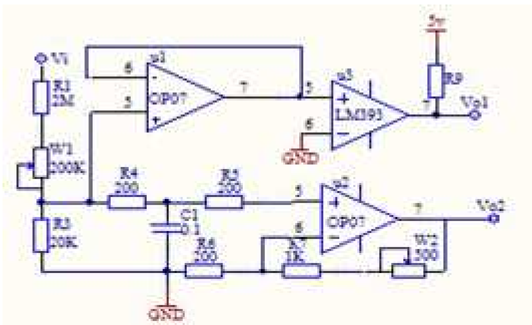

Figure4 Three Phase Current Sampling Circuit

3.2 Design of Interface Circuits of AD Converter and M3 Microcontroller

3.2.1 Instruction of STM32

The STM32F103C8T6 performance line family incorporates the high performance ARM Cortex™-M3 32-bit RISC core operating at a 72 MHz frequency, high speed embedded memories and an extensive range of enhanced I/O and peripherals connected to two APB buses. The STM32F103C8T6 medium-density performance line family operates from a 2.0 to 3.6 V power supply. It is available in both the –40 to +85 °C temperature range and the –40 to +105 °C extended temperature range. A comprehensive set of power-saving mode allows the design of low-power applications.

The STM32F103xx medium-density performance line family includes devices in six different package types: from 36 pins to 100 pins. Depending on the device chosen, different sets of peripherals are included, the description below gives an overview of the complete range of peripherals proposed in this family. These features make the STM32F103xx medium-density performance line microcontroller family suitable for a wide range of applications.

3.2.2 Design of interface circuits of AD7656-1 and STM32

Because of the numerous basic data from AD7656-1, one parallel interface circuit, as shown in figure 5, was adopted to decrease the holding time of CPU.

AD7656-1 is the upgrades of AD7656, it contains six 16-bit, fast, low-power, SAR ADCs, six track-and-hold amplifiers and high speed parallel and serial interfaces. It allows the simultaneous sampling of all six ADCs when all three CONVST signals are tied together. Alternatively, the six ADCs can be grouped into three pairs. Each pair has an associated CONVSY signal (CONVST A B C) used to initiate simultaneous sampling on each ADC pair, on four ADCs, or on all six ADCs. CONVST A, CONVST B and CONVST C were connected to PB7, PB6, PB5 respectively and were triggered once there is a peripheral interrupt, the VDRIVE pin was connected to 3.3V to match electrical level of AD7656-1.

3.2.3 The configuration of STM32's interruption system

In this paper, the PB8 of STM32 was configured as peripheral interrupt and acquire signal from PLL circuits. The configuration procedures of STM32 are described as follows: firstly, PB8 was configured as pull-up working condition and then external register EXTICR was configured to trigger multiplexed clock signal, the peripheral interrupt signal was connected to the internal interrupt Pins, and was configured as falling edge is effective, the NVIC register was finally configured to enable interrupts.

3.2.4 Algorithm of electrical parameters calculation

The voltage, current, active power, reactive power and the phase can be obtained easily by calling subroutine of STM32, and these data as above mentioned were processed by FFT prior to use.

3.3 The Other Related Circuits

Other related circuit mainly included communication circuit which adopted RS485 interface circuits, clock circuit which adopted DS1302 chip, memory circuit which adopted AT24C256 chip, display circuit which adopted LCD module, and the keying circuit which adopted special keyboard module, all of them were not discussed in detail here.

4. DESIGN OF SYSTEM SOFTWARE

The function of software of the monitoring terminal system is to realize electrical parameters measurement at the regulation time according to Chinese GB/16664-1996 in one test period (that is, 24 hours) and to upload them to upper computer. The parameters mentioned here include voltage, current, average power, maximum power and power factor. The main program flow char of monitoring terminal is as shown in figure 6.

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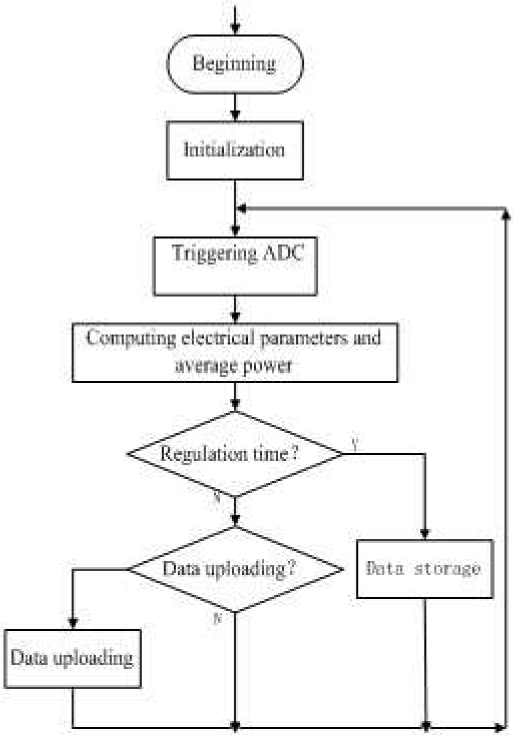

Figure6 Main Programming Flow Chart

N data was measured in one test period, and electrical parameters, such as voltage, current, active power and reactive power et al were calculated by FFT subroutine of STM32. At the each regulation time of test period, these date about electrical parameters were stored and were upload to upper computer when one test period is completed. These data mentioned here were analyzed by upper computer to obtain daily load factor and load coefficient of transformer, line cost rate and power factor of enterprise power system. According to all of these data, the overall energy efficient status of enterprise power system is obtained.

5. EXPERIMENTAL RESULTS

Voltage, current are tested in laboratory, with a multi meter HP34401 and Power supply WT-

160. The method is adjusting the HP34401 to display the standard value, at the same time, recording the terminal's testing data. The single phase voltage testing results and the single phase current testing results are showed in table 1 and table 2.

In table1 and table 2, the data simulates the output of low voltage metering device, and it shows that the testing error is less than 0.1%.

$$\gamma_U = \frac{U_X - U_O}{U_O} \times 100\% = \frac{80.04-80.00}{400.00} \times 100\% = 0.01\% \quad (1)$$

$$\gamma_I = \frac{I_X - I_O}{I_O} \times 100\% = \frac{0.502-0.500}{5.000} \times 100\% = 0.04\% \quad (2)$$

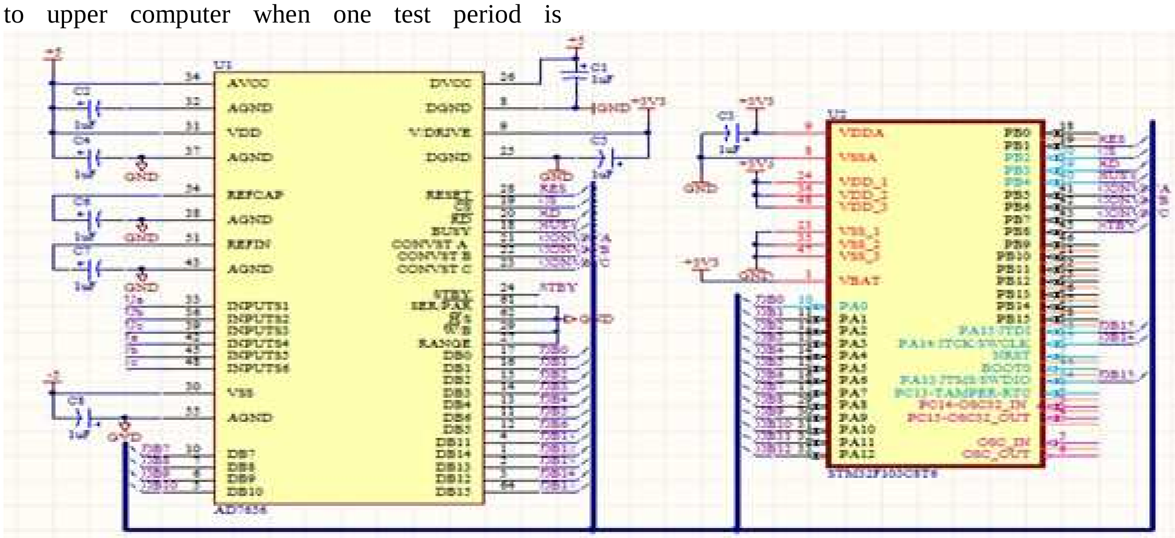

Figure.5 Interface Circuit Of AD Converter And M3 Microcontroller

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Table 1. Testing Results Of Voltage

Standard voltage(V)	80.00	90.00	110.00	200.00	220.00	240.00	350.00	380.00	440.00
Testing voltage(V)	80.02	90.02	110.01	200.01	220.01	240.01	350.01	380.00	439.98

Table 2. Testing Results Of Current

Standard current(A)	0.500	1.000	2.000	2.500	4.000	5.000	6.000
Testing current(A)	0.502	1.002	2.001	2.501	4.001	5.000	5.998

In equation (1) and (2) U_O , I_O are the range of voltage and current respectively and U_X , I_X are the testing values respectively which has maximum error to the range.

6. CONCLUSIONS

The energy-efficient monitoring terminal based on STM32F103 was presented in this paper, and the adoption of AD7656-1 has greatly reduced their cost and provided appropriate function to users, and it has real time measurement function and higher measurement accuracy.

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