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ARTICLE

ANALYSIS AND REALIZATION OF THE SYNCHRONOUS SAMPLING OF THE POWER NETWORK PARAMETERS WITH THE DOUBLE POWER SUPPLY AUTOMATIC TRANSFER SWITCH

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ABSTRACT

Classic of AC (Alternating Current) sampling for power network signals was introduced working principles and error resources in realizing period rounding error and their compensation methods were proposed. Thoughts to keep synchronous when power network was distorting were discussed. According to sampling requirements for power network parameters of double power resources automatic transforming switch, combining ARM technology, a software synchronous sampling system realization scheme based on LPC2318 and MAX123 was proposed. Using this method to measure double power sources automatic switch power network signal's effective value power higher harmonic and recording faults hardware complexity can be lowered and accuracy ensured. It can synchronously avoid measurement error of voltage and current phase difference, greatly reduce period error, shorten sampling time and enhance measuring accuracy. Designing changing frequency synchronous sampling overcomes sensitivity of common AC sampling to period, and enhances sampling accuracy and reality as well.

KEYWORDS

Double Power, Sources Switch, Period Rounding Error, Variable Rate Synchronous Sampling.

1. INTRODUCTION

With the continuous improvement of the level of electric power automation, the quality of electric power has been paid more and more attention by people. The continuity of power supply is an important aspect of power quality. Some key departments and units with special needs (such as government, military confidential, post and telecommunications, airports, subways, stations, hospitals, large production lines, etc.) have very high requirements for uninterrupted power supply. The conventional practice is to provide the main and backup two independent power supplies to the power supply object. The main function of the dual power supply automatic switching system is to accurately complete the switching between the main power supply and the backup power supply according to the set switching procedure when the main power supply fails, so as to ensure the continuity of the power supply to the greatest extent. As the core control component of the dual power supply intelligent switching system, the intelligent controller samples and calculates the voltage and current frequency of the power supply circuit, and realizes the identification and switching functions of phase loss, undervoltage, overvoltage, short circuit, overload, overclocking and other faults. Compared with the traditional dual power switching system, the intelligent controller makes the dual power switching system have a great development. For example, the range of undervoltage, overvoltage, overload, and overclocking faults can be flexibly set on site. At the same time, it has running status display, fault memory, communication and other functions. Such changes make the dual power intelligent switching system stand out in the field of low-voltage electrical appliances. In addition to the measurement of electrical parameters such as voltage, current, power and power factor, the power supply intelligent switching system can also measure the power quality in the power grid (including the measurement of high-order harmonics). Intelligence and communication have become the prominent features of the dual power supply intelligent switching system.

The most important thing in the power supply automatic switching system is the acquisition of power parameters, which puts forward high requirements on the sampling accuracy. The acquisition of power parameters can be divided into two categories: DC sampling and AC sampling. The DC sampling circuit and algorithm are simple, but the delay time is too large, and real-time sampling and power harmonic analysis cannot be realized; the AC sampling has good real-time performance and small sampling distortion, and the disadvantage is that the algorithm is complicated. To achieve high precision, the AC synchronous sampling bar must be used. Traditional synchronization methods include hardware type and software type. Purely using hardware or software to achieve synchronization has disadvantages. Reasonable use of hardware synchronization and software error correction processing can not only improve accuracy and reliability, but also reduce cost. The AC synchronous sampling based on the combination of hardware synchronization and software synchronization is adopted, and the AC quantity is directly collected by the A/D converter according to a certain rule, and the AC power parameters such as voltage, current RMS,

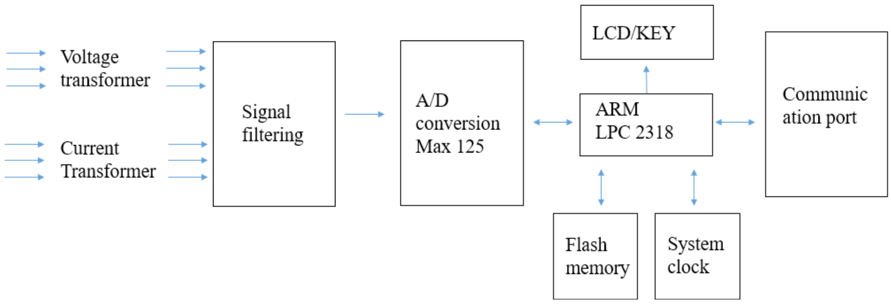

Figure 1: Block diagram of an AC sampling system composed of ARM LPC2318 and MAX125

and active power and reactive power are obtained by FFT operation. Hardware and software integrated synchronous AC sampling reduces the cost of the device and simplifies the system structure. It can realize the calculation of various AC power, the measurement function is strong, the measurement accuracy is improved, and the setting is convenient. The measurement and control device of the dual power supply automatic switching system based on the AC sampling method can be reduced in size, and the weight is also reduced a lot. The communication function of the controller can be used to set the measurement coefficient online, and it is of great benefit for future algorithm improvements and system upgrades.

The non-simultaneous sampling of voltage and current will cause the measurement error of each phase voltage and current phase difference. When high-order harmonic analysis is performed, it will cause a large calculation error [2]. In addition, most of the current theories and algorithms for measuring and analyzing periodic electrical signals using sampled values are based on synchronous sampling. However, it is difficult to achieve ideal synchronization in actual engineering sampling. There are synchronization errors, which made data analysis and measurement inaccurate. To solve these problems, A/D converters with better performance, faster speed and simultaneous sampling must be used in hardware, and existing synchronization methods should be improved in software, so as to decrease the synchronization error and the unevenness of sampling interval to the maximum degree. This paper introduces a synchronous AC sampling technology integrated by hardware and software of intelligent dual power supply automatic switching system. It focuses on analyzing the working principle and error source of synchronous AC sampling using software. It designs a method that can simultaneously sample multiple measured instantaneous values. The hardware circuit proposes a software quasi-synchronous sampling algorithm capable of compensating for period rounding error and period variation error. Since this technology can simultaneously quasi-synchronously sample multiple measured instantaneous values, it has good real-time performance, small phase distortion, and accurate measurement. It fully meets the acquisition requirements of dual-power automatic switching systems for power parameters.

2. DESIGN OF HARDWARE SIMULTANEOUS AC SAMPLING SYSTEM

AC sampling is to sample the instantaneous value of the measured signal, and then analyze and calculate the sampled value to obtain the measured information. The sampling rate of AC sampling is required to be high, and the program calculation is relatively large, but its sampling value contains a large amount of information. Various algorithms can be used to obtain the required information (such as RMS, phase, harmonic components, etc.) with good real-time performance. With the development of ARM technology, high-speed real-time data processing becomes possible, and AC sampling has become the current main way.

Compared with the general industrial measurement and control system, the power parameter detection system has the following characteristics [3].

(1) It is required to sample the voltage and current signals at the same time, and there is no difference between the two to facilitate the calculation of power and power factor.

(2) It is necessary to perform spectrum analysis on the signal, which involves a large number of signal processing operations such as filtering and FFT, and the real-time requirements for signal processing are relatively high.

(3) The sampling frequency is required to be synchronized with the signal frequency to reduce the influence of spectral leakage on the accuracy of harmonic analysis.

Figure 1 is a block diagram of an AC sampling system composed of ARM LPC2318 and MAX125. The peripheral hardware of the system should also include a liquid crystal display (LCD), keyboard, massive Flash memory, system clock and calendar, communication port (network card or RS-232C), and so on. They are the hardware that guarantees the system achieves the specified task.

AC sampling is to convert the voltage and current in the power grid into small AC signals that can be measured by the ARM through high-precision CT and PT, and then send the small AC signals to the ARM for processing. The output of the zero-crossing trigger circuit is connected to the external interrupt of LPC2318 to ensure the real-time response of the interruption. At the same time, the output of the zero-crossing trigger circuit is also connected to the input end of the capture unit. Because the LPC2318 has multiple general-purpose timers, only use two timers, T1 and T2, are used as the time base of the capture unit, then the capture unit can capture the time between two pulses. In this way, the period and frequency can be calculated. Then use the obtained frequency and the number of sampling points to determine the sampling period to start the ADC to perform an A/D conversion.

The MAX125 chip integrates multiple sample-and-hold devices, analog multiplexers, and high-speed A/D converters with a +2.5V voltage reference. It can work in the cyclic sampling mode of 4 input channels of the two groups of AB, and the on-chip timing controller controls the switching of the channels. In the default mode, the outputs of the 4 sample and hold amplifiers in group A are converted from 1 channel to 4 channels in turn. When all 4 channels are converted, an interrupt signal is generated to the outside. Reprogramming the MAX125 through the bidirectional parallel port of the MAX125 can make it work on several preset channels so that the MAX125 will always convert the given channel until it is reprogrammed. The conversion time of a single channel is 3μs. After the conversion is completed, the result is stored in the 4×14bit RAM inside the chip. After the external circuit receives the interrupt signal sent by all conversions, it can sequentially apply read pulses to the enable pins of the MAX125 to read out the conversion result.

The 32-bit ARMLPC2318's high-speed instruction execution capability and powerful mathematical calculation capability meet the second requirement of the above-mentioned characteristics of power parameter detection. MAX125 two groups of 4 input channels, multi-sampling and holding device, ensures the simultaneous sampling of voltage and current signals. There is no difference between the two to facilitate accurate calculation of power and power factor. However, the problem of spectral leakage still exists, and further simultaneous sampling processing is required.

3. IMPLEMENTATION OF SOFTWARE QUASI-SYNCHRONOUS SAMPLING

A synchronous sampling of the whole cycle is the basis of power parameter measurement and analysis, and it is the fundamental measure to reduce spectrum leakage in the harmonic analysis [4]. Perform AC sampling on the measured electrical signal with a period of T at t_0, t_1, ...t_i, ...t_N (i=01...N). Let t_0=0 if there are:

$$\Delta t = t_N - T = 0 \tag{1}$$

$$\Delta t_i = t_i - 1 - T_i = T_s \tag{2}$$

If equations (1) and (2) are established, the sampling is called ideal synchronous sampling, and T_s is the sampling period. It can be seen that the ideal synchronization must meet two conditions: 1. the signal period and the sampling period have an integer multiple relationships; 2. the time interval between the sampling points should be strictly consistent. But synchronization is relative, the absolute synchronization is only an ideal situation. For occasions with high detection accuracy requirements, the synchronous sampling method is more commonly used. It has two synchronization modes: hardware mode and software mode. The hardware synchronization method is to use the phase-locked loop to track the change in the fundamental frequency of the signal in real time and to adjust the sampling frequency in real time to achieve synchronization. It is a preventive method, the hardware structure is complex when the signal has large distortion or strong noise, the error is large, and the reliability is not high. Therefore, the hardware method is used less. The software synchronous sampling is realized by the timer interrupt. It first measures the grid period T and then determines the timer value T/N according to the period T and the number of sampling points N in each period. Software synchronization does not require a dedicated synchronization circuit. Compared with hardware synchronization, its hardware structure is simple. It only needs to set up the power grid frequency tracking measurement link in the microcomputer sampling device. Software synchronous sampling is achieved by sampling and resetting the timer value in the timed interrupt service routine. The timing value is determined according to the grid period T and the number of sampling times N per cycle. Synchronization conditional expression (1) is more difficult to satisfy when software is synchronized. That is, Δt is not 0. Δt or Δt/N is called the synchronization error. In the actual measurement system, since the counting period of the timer cannot be infinitely small, the sampling interval must be represented by an integer multiple of the minimum counting period of the timer, and its value is a positive integer, so there is a rounding error. The accumulation over a signal cycle introduces periodic rounding errors. In addition, due to the slow change of grid frequency, the sampling period T_s during sampling is always determined according to the grid period measured before that, so there is an error between the actual period value of the sampled signal and the measured value during sampling, which results in a periodic variation error. The periodic rounding error and the periodic variation error work together to form the synchronization error. The synchronization error is the main reason that affects the accuracy. Therefore, some improvement algorithms must be taken.

3.1 Compensation for periodic rounding error

If the count period of the timer is τ, the count value of the timer corresponding to T_s is T_s/τ. It is generally not an integer and truncates the decimal to round it to obtain an integer I. The truncated fractional part is L, namely:

$$I = \operatorname{int}(T_s / \tau); L = T_s / \tau - \operatorname{int}(T_s / \tau) \tag{3}$$

Obviously, the value of T_s/τ is between I and I+1. Regardless of whether I or I+1 is used as the count value of the timer, there is an error between the actual sampling period and the ideal sampling period. The accumulation of this error results in a cycle. rounding error. Therefore, it is necessary to improve the current practice of taking the timer count value as a constant in the sampling process to reduce the cycle rounding error [5].

The accumulating unit is set to accumulate the deviation L, and the value of the accumulating unit is set as Ni at the i-th sampling. The value of Ni should be checked before each sampling. If Ni<0.5, the timer count value of this sampling is 1; if Ni>0.5, the timer count value of this sampling is I+1; at the same time, we fix Ni to Ni = Ni-1. We continue the above process until the sampling of one power frequency cycle is completed. Obviously -0.5≤Ni≤0.5 and it is easy to see that the periodic rounding error $\Delta i = N_i \tau_0$ of the i-th sampling. So the periodic rounding error $|\triangle i| \leq 0.5\tau_0$. It can be seen that the improved method can make the deviation not accumulate, so as to ensure that the maximum cycle rounding error Δi caused by L in one power frequency cycle is not greater than half of the minimum resolution time τ of the timer. The biggest advantage of this method is that it only needs to add a few instructions to the original timer interrupt sampling program, and does not need to make any changes to the hardware and measurement algorithm. It can greatly reduce the synchronization error and greatly improve the software synchronization accuracy. In addition, the interrupt response time of ARM interrupt processing will also introduce errors in each interrupt, and the error will accumulate into a cycle error. Therefore, the interrupt response time must be subtracted when the timing value is reset. During the sampling process, the error caused by the interrupt response time will not increase as the number of sampling points increases, at the same time, the synchronization error will be greatly reduced.

3.2 Compensation of periodic variation error

A virtual sample function with the same period as the sampling signal is constructed inside the ARM. When the signal frequency deviates from the frequency of the sample function, the phase of the signal and the sample function will change continuously, as shown in Figure 2. In the figure, the solid line is the signal waveform (fundamental wave), and the dashed line is the sample function waveform.

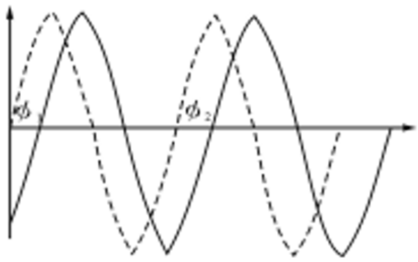

Figure 2: Schematic diagram of compensation for period variation error

Assuming that the two adjacent phase differences are ϕ_1 and ϕ_2, respectively, then:

$$\Delta\phi = \phi_2 - \phi_1 \tag{4}$$

$$\Delta T = Tk \bullet \Delta\phi / 2\pi \tag{5}$$

$$T_{k+1} = T_k + \Delta T \tag{6}$$

In the formula: ΔT is the sampling period correction amount, and T_{k+1} is the next sampling period. If the number of sampling points is taken as N, the period of the signal $T = N \times T_{k+1}$, then the frequency of the signal can be calculated as $f = 1/(N \times T_{k+1})$

This compensation method is essentially sampling at a variable sampling rate. The compensation method for this period variation error is not as accurate as the hardware synchronization method. However, the reliability is high. After each sampling is completed, the sampling period and synchronization point correction in this way can be used to obtain accurate synchronization time and period with high reliability.

The synchronous sampling process that integrates the above two error compensations is as follows [6]. After the system is powered on and the ARM and MAX125 are initialized respectively, the ARM receives the signal from the zero-crossing trigger circuit and sends it to the external interrupt and capture unit. The capture unit captures the time between 2 pulses so that the period and frequency can be calculated and compensated for the period variation error and the period rounding error using the synchronized sampling method mentioned above. After the sampling period is determined, the timer starts timing, and the MAX125 starts an A/D conversion when the next pulse arrives. At this time, the MAX125 samples select 4 input voltage and current signals at the same time according to the initialization mode and then convert these signals in sequence. The conversion time of each signal is 3μs. After the conversion of all channels is completed, the output of MAX125 becomes low level, which triggers the external interrupt of ARM. The interrupt subroutine gets started to read the sampled data, the sampling ends, and MAX125 and ARM wait for the next sampling.

The test shows that under the condition of power frequency (50Hz±5Hz), the measurement accuracy of AC frequency using this sampling method can reach 0.01%, the measurement accuracy of AC power factor can reach 0.1%, and the measurement accuracy of AC current and voltage is better than 0.2% Simultaneous The experiment proves that the simultaneous sampling method of variable sampling rate based on the combination of software and hardware will not affect the measurement accuracy under the condition of large power frequency fluctuation. Theoretically, this sampling method can be suitable for power frequency, intermediate frequency, and even high-frequency AC. Precise measurement of sinusoidal electrical parameters In the AC measurement system with a large frequency fluctuation range and frequent fluctuations, this method is not sensitive to the frequency change of AC, and the measurement stability and accuracy are better.

4. CONCLUSION

The variable sampling rate simultaneous synchronous sampling module based on the combination of software and hardware of ARMLPC2318 and MAX125 designed in this paper has passed various functional tests in the measurement and control device of the intelligent dual power automatic switching system. The measurement accuracy and reliability have been verified. expected target. It is very suitable for the precise measurement of three-phase AC parameters with strong interference, large signal distortion, and large frequency fluctuation.

This high-resolution MAX125-based A/D sampling system eliminates the measurement error of the voltage and current phase difference due to the simultaneous sampling of the voltage and current of each phase, which facilitates the accurate calculation of power and power factor. The variable sampling rate software synchronous sampling method, which implements period rounding error and period variation error compensation, overcomes the sensitivity of ordinary AC sampling to the period, greatly reduces the period error, shortens the sampling time, and improves the measurement accuracy and reliability. This scheme has a certain reference value for all power AC measurements.

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