Design of distributed power quality monitoring system for distribution house

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Abstract. The construction of smart grid puts forward higher requirements for power quality. As the key node of power distribution system, power quality monitoring of distribution room has always been the weak link of power operation and maintenance. This paper presents a distributed power quality monitoring system for distribution room, which includes hardware design and software design. It has the functions of acquisition, analysis, display and communication. It can complete distributed power quality monitoring for multiple outgoing branches of distribution room. The application of this system can provide data support for power quality analysis and management of low-voltage distribution system.

1. Introduction

With the continuous progress of national economy and science and technology, electric energy has become the most widely used and indispensable energy in human society, and the requirements for power quality in all walks of life are becoming higher and higher. Due to the non-linear, impulsive and unbalanced characteristics of load in power system, power quality problems such as voltage and current waveform distortion, voltage fluctuation and flicker, harmonic content increase, voltage sag, and three-phase unbalance seriously affect the quality of power supply [1]. In the standards issued by IEC in recent years, besides making appropriate modifications to the original voltage, current and frequency levels, it has also greatly expanded its work field, involving the power quality of smart grid, distributed power generation, micro-grid and public power grid [2].

Distribution room, as the main place of electrical equipment to transmit and distribute electric energy in the distribution network at the end of power system, is an important part of distribution network system. Its power supply quality is directly related to the reliability and quality of power consumption of users. Because there are a large number of non-linear loads in the distribution network, they will have a serious impact on bus voltage and frequency in the distribution network. Once the power quality problems occur in the distribution network, it may cause equipment failure and outage, which has serious harm to the safe operation of the distribution network.

State Grid Corporation proposes that the important material basis for building world-class energy Internet enterprises is to build and operate "two networks" (i.e. "ubiquitous power Internet of things" and "strong smart grid"), achieve business collaboration, data transmission and unified management of the Internet of Things, and comprehensively form an energy Internet ecological circle of co-construction, co-governance and sharing [3]. After the vigorous construction of power generation, transmission and distribution links, most of the power supply and transmission line skeleton in China have been gradually improved. At present, the focus of power construction continues to extend
downward, focusing more on the two links of distribution and electricity. At present, the unqualified rate of 380/220 V voltage level with the largest number of users is the highest, which has also attracted great attention of the power sector. The state has promulgated technical standards related to power quality, which are implemented and guaranteed by the power sector. Distribution house is the key node of power system [4]. For a long time, its power quality monitoring and management has been one of the weak links of power supply reliability of distribution system, which does not meet the development needs of building smart grid.

Based on the demand of power quality monitoring in distribution room and the development idea of "ubiquitous power Internet of things" in the construction of national power grid, this paper develops distributed power quality monitoring terminal in distribution room, realizes on-line distributed monitoring of power quality in multi-outlet branch of distribution room, and provides data support for power quality analysis and management of low-voltage distribution system.

2. Distributed power quality monitoring system architecture for distribution house
Distributed power quality monitoring terminal in distribution room mainly includes signal acquisition module, power supply module, AD module, storage module, data processing module, communication interface module, man-machine interface module, etc [5]. Its basic structure is shown in figure 1. The main functions of each module are as follows:

- **Signal acquisition module:** The module collects bus voltage and switchgear outgoing current through transformer, and processes the signal by filtering, amplifying and zero-setting.
- **Power supply module:** This module provides power for the whole device to ensure the normal operation of the device;
- **AD module:** The module sampled the voltage and current signals after conditioning. The function was realized by 8-channel 16-bit sampling chip AD7606.
- **Storage module:** The module stores monitoring data in 64G extended SD card, which can store monitoring and analysis data for a long time.
- **Data processing module:** This module is the core of the whole device. It uses DSP processor to realize the functions of data acquisition, storage, data analysis and communication.
- **Communication interface module:** real-time and high-speed data transmission through various communication modes to complete the communication with the host computer.
- **Man-machine interface module:** This module is responsible for the visualization of the analysis results, making the human-machine interaction function more convenient.

3. Hardware circuit design

3.1. Signal conditioning circuit
The function of signal conditioning circuit is to filter and zero-adjust voltage and current signals [6].
The working principle diagram is shown in figure 2. The output voltage amplitude of signal conditioning circuit is less than 5 V.

![Diagram of Signal Conditioning Circuit]

**Figure 2.** Hardware circuit diagram.

### 3.2. AD conversion circuit
AD7606 is used in AD conversion chip, which is a 16-bit high-speed and high-precision analog-to-digital conversion chip with 8-channel synchronous sampling. It supports parallel acquisition and conversion of 200 Kbps sampling rate in the whole channel [7]. The input voltage range of the signal acquisition module is (+5 V) bipolar signal, and the sampling frequency of the device is set to 10.24 kHz. The circuit diagram is shown in figure 2.

### 3.3. Processor module
The main processor module uses dual-core processor of DSP+ARM, and its circuit diagram is shown in figure 2. The main function of the DSP data processing module is to calculate and process the voltage and current signals output by AD in real time, and transmit the operation results to AMR to complete data management, display and communication [8].

### 3.4. Communication module
In order to monitor the power data intuitively, it is necessary to transfer the collected data to the back-end server of the client for analysis, and change the equipment parameters at any time according to the operation of the site by the back-end management software.

The collected electric energy information such as grid voltage and current is transmitted to the back-end server by the way of wireless transmission in the mode of 4 G communication. RS-485 communication mode with simple structure, appropriate communication distance and data transmission rate is adopted to transmit instructions from the background server to the microprocessor. The circuit diagram of the communication module is shown in figure 2.

### 3.5. Power module
The main function of the power supply is to provide a stable 3.3 V and 5 V voltage for the core board. In addition, the module also includes restart function. The schematic diagram of the power supply module is shown in figure 2.

3.6. Human-computer interaction module
ARM uses embedded operating system platform, which is responsible for system scheduling, realizes human-computer interaction, parameter setting and saving, communication interface, SD card interface and other functions. Its hardware function block diagram is shown in figure 3.

4. Software function design

4.1. Software design of DSP
The software part of DSP includes the initialization of DAP and AD, the control of AD chip for signal sampling, the processing of the collected signal, and the transmission of the results of the calculation to ARM for display and communication [9].

DSP realizes the calculation of basic indexes of power quality: three-phase voltage RMS, three-phase current RMS, power, phase, power factor, etc; voltage deviation; frequency deviation; three-phase unbalance, negative sequence voltage and current; total harmonic distortion rate of voltage, total harmonic distortion rate of current, harmonic content rate of each harmonic; active and reactive power of each harmonic, etc.

The main task of the DSP system is to process and calculate three-phase voltage and current data, obtain various power quality data to be monitored, upload or store them according to the system requirements, and control the AD conversion chip for AD conversion. The main program flow is shown in figure 4.

4.2. Software design of ARM
The main function of ARM is to get data by communicating with DSP. It is responsible for completing human-computer interaction, displaying and storing data and transmitting data to PC. ARM chips are mainly responsible for communication, human-computer interaction management, receiving keyboard interruptions, displaying and storing according to the keyboard requirements. At the same time, ARM chips can also receive the interruptions of the host computer, and display, communicate and store the corresponding parameters according to the requirements of the host computer. In addition, the ARM
chip can receive the interruption of signal processing unit and receive and store data according to the interruption request of the DSP [10]. The main program flow is shown in figure 5.

![Figure 5. Flow chart of ARM software design.](image)

5. System display interface
A good display interface can make the software have a human-machine interface and facilitate the use and observation of the software. The interface of the power quality monitoring system developed in this paper is shown in figure 6. It can display basic power quality parameters such as three-phase voltage RMS, voltage deviation, three-phase current RMS, current deviation and frequency deviation.

![Figure 6. Power quality system interface.](image)

6. Conclusions
Based on the dual-core system of DSP and ARM, this paper designs and develops a power quality detection device, which meets the distributed monitoring requirement of multiple outgoing lines in distribution room. Local real-time display of power quality parameters and voltage and current harmonic analysis graphics, tables, etc. The device is tested, and the correctness and feasibility of the hardware and software design of the device are verified. The power quality system of distribution room developed in this paper can effectively improve the power quality management level of distribution room and promote the reliability of power supply of distribution system.

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