Power quality monitoring system of distribution room based on distributed sensors

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Abstract. A large number of non-linear devices has been used nowadays. Therefore, the power quality problem on the user side is becoming significantly prominent. The power distribution room is the end of the power system, which is directly connected to the users. But distribution room has noneffective power quality monitoring system established due to difficulties of data measuring and installation. In this paper, based on micro distributed sensor with coil energy acquisition and wireless communication technology, a distributed power quality monitoring system is developed in distribution room, which can be implemented quickly and complete the monitoring and analysis of power quality information in the distribution room. The system realizes the function of design requirement through field test.

1. Introduction

10kV distribution room is an important electrical node for electricity transmission and distribution. The outgoing line of the distribution room will face the user directly, and the power quality of the distribution room will directly affect the user's electricity use experience\cite{1-2}. With the development of industry and the increase of frequency conversion equipment for civil use, the users produce a lot of electric harmonics. Therefore, all users of the outgoing line in the same power distribution room will face similar power quality problems. Then, for a long time, the distribution room has a weak operation and monitor system because of several reasons, which is showed as follows\cite{4-6}.

A. The running status of the equipment cannot be monitored. There are a large number of equipment in the power distribution room. At present, the equipment only operates locally and has no interaction with electricity-producing worker.

B. Power quality cannot be monitored. At present, current transformer is only data source for current power quality monitoring. So that a complete power quality monitoring system does not have all the data channel for voltage and current monitoring in the distribution room without CT\cite{6-7}.

C. The installation of monitoring system is difficult. All kinds of monitoring equipment in power distribution room are not suitable for large-scale promotion due to the limitation of principle which has the problem of complicated installation\cite{8}.

In order to solve the practical problem of power quality monitoring in distribution room, this paper will carry out the research on power quality monitoring technology based on the new micro distributed current sensors. This system can be installed rapidly and easily with the technology of energy-gaining coils and wireless communication. All power quality data will be stored and processed remotely through wireless transmission. The system will accomplish power quality monitoring and analysis,
load characteristic analysis and other functions, which will improve the reliability of distribution network.

2. Monitoring system architecture

2.1. Monitoring system topology

The core problem of power quality monitoring in distribution room is the restriction of monitoring data source and the complexity of installation.

The basic composition of the distribution room is the switch cabinet or the ring network cabinet, which can transmit electricity to multiple users by switching on or off the single or multiple incoming and outgoing lines. The key of power quality monitoring in distribution room is to measure the power quality of all incoming and outgoing lines[9].

In this paper, in order to measuring power quality, three hardware terminals are designed, include current quality monitoring terminal, voltage quality monitoring terminal and power quality data collection terminal. Its architecture is shown in figure 1.

![Figure 1. Power quality monitoring system architecture.](image)

The current quality monitoring terminal can collect the current data through the micro-sensor which can be installed in the location without CT. Three distributed terminals will be installed as ABC phases besides each incoming and outgoing line.

The voltage quality monitoring terminal calculates the voltage and power quality by the data from PT. Since each incoming and outgoing line in the distribution room is designed as a common bus, only one voltage quality terminal needs to be installed in a distribution room.

The power quality data collection terminal will provide the channels for upload and receiving. The receiving channel will receive the data transmitted by the monitoring terminal, and establishes the relationship between each terminal. With all the coupling date, power quality characteristics will be calculated in the side of collection terminal. The upload channel will transfer all the computed data to the remote database.

In the monitoring system, all data communication is wireless, which simplifies the installation process by reducing communication cables.

Due to the small number of 10kV nodes in the distribution room, the typical configuration of the terminals in a distribution room is shown in table 2.

| Num | Terminal name                  | Amount |
|-----|--------------------------------|--------|
| 1   | Current quality monitoring terminal | 12     |
| 2   | Voltage quality monitoring terminal | 1      |
| 3   | Power quality data collection terminal | 1      |

2.2. Data flow of monitoring system

The data flow of the monitoring system is shown in figure 2. The core of communication data flow is power quality data collection terminal, which will upload and receive data. In a single distribution room, there will be multiple monitoring terminals which are connecting with the data collecting
terminal at the same time. Meanwhile, data collection terminal shall establish multiple receiving channels to receive data. Besides, the working state of each sensor needs to be controlled through the data collection terminal.

![Figure 2. Data flow of monitoring system.](image)

### 3. Power quality monitoring terminals

#### 3.1. Current quality monitoring terminal

**3.1.1. Hardware design**

The most important function of current quality monitoring terminal is to complete the real-time collection of current data and analysis of current power quality through calculation. Meanwhile, in order to install the terminal quickly and easily, the monitoring terminal will adopt technologies such as coil energy acquisition and wireless communication. The terminal is composed of sensor module, power module, analog data processing module, digital signal processing module and remote transmission module, as shown in figure 3.

![Figure 3. Components of current quality monitoring terminal.](image)

The power module will acquire energy from coil, and will form a composite power supply system together with the lithium battery. In order to ensure the efficiency and safety of the power module, the number of coil turns and the section area of the energy collection magnetic ring are optimized during the circuit design. Besides, the saturation characteristic of magnetic material and the buffer of TVS tube are used to guarantee the security of power supply under the large current shock.

The sensor module completes the measurement of the current through measuring the magnetic field around the conductor, and generates the time-amplitude sequence of the current through analog and digital signal processing module. In order to achieve the analysis of 49 harmonics, the sampling rate of the terminal is 5kHz. In the design, components of terminal include STM32(MCU), ADS7057(High speed AD), CC2640R2F(Wireless communication), etc. The circuit diagram is shown in figure 4.
According to the requirements of IEC, national standards and industry standards, the data to be monitored and analyzed by a single current quality monitoring terminal is shown in Table 2. The system with multiple current sensors also needs to complete the measurement of three-phase imbalance.

Table 2. Current quality monitoring items.

| Item | Details |
|------|---------|
| Steady-state parameters | Amplitude, Frequency |
| First harmonic | Current amplitude, Current phase |
| Harmonics | Total current harmonic distortion rate |
| | Total odd harmonic distortion rate of current |
| | Total even harmonic distortion rate of current |
| | RMS and distortion rate of 2~50 harmonic current |

At the current terminal, the digital signal will be calculated according to the calculation requirements to form the basic current quality characteristic data, and uploaded to the data collection terminal according to the data file format. Its working logic is shown in Figure 5.

Figure 5. Digital signal logic of current.

3.2. Current quality monitoring terminal

(a) Hardware design

The voltage quality monitoring terminal will measure PT output signal and analyse voltage quality through calculation. The difference between this terminal and the existing equipment is that it transmits data wirelessly.

This terminal includes sensor module, power module, analog data processing module, digital signal processing module and remote transmission module. The power module only converts the external input power to the power supply voltage suitable for the electronic components in the terminal through multi-stage transformation.
The sensing module of the voltage quality terminal contains three sensors to measure the ABC three-phase voltage. The terminal can use for measurement in three-phase four-wire system and three-phase three-wire system with the design of PCB.

(b) Work logic

According to the requirements of IEC, national standards and industry standards, the data to be monitored and analyzed by voltage quality monitoring terminals are shown in table 3.

| Item                  | Details                                      |
|-----------------------|----------------------------------------------|
| Steady-state parameters| Amplitude, Frequency, Three-phase imbalance |
| Transient parameters  | Fluctuation, Flicker                         |
| First harmonic        | Voltage amplitude                            |
| Harmonics             | Voltage phase                                |
|                       | Total voltage harmonic distortion rate        |
|                       | Total odd harmonic distortion rate of voltage |
|                       | Total even harmonic distortion rate of voltage|
|                       | RMS and distortion rate of 2~50 harmonic voltage|

The digital signal will be calculated according to the calculation requirements to form the basic voltage quality characteristic data, and uploaded to the data collection terminal according to the data file format. Its working logic is shown in figure 6.

3.3. Current quality monitoring terminal

(a) Hardware design

At the data collection terminal, it is necessary to complete the relationship and data structuring of distributed monitoring terminal. In order to make sure the time synchronization of voltage and current terminal, the collection terminal shall acquire the accurate time and transmit the time information. In the hardware design, this terminal is mainly composed of power module, multichannel local area communication module, GPS/Beidou module, 4G/LTE communication module and serial port/RJ45 output module. 4G, RS485 and RJ45 can transmit data outside.

(b) Work logic

The main working logic of collection terminal is divided into downlink logic, uplink logic, data processing logic and system configuration logic.

Downlink logic is the two-way transmission channel between collection terminal with voltage terminal and current terminal. Specifically, the collection terminal issues timing information and
control commands and receives current and voltage data from the voltage and current terminals. The uplink logic is the transmission channel with the remote centre. The data after analysis will directly pass through multiple transmission ports.

System configuration logic is the configuration of internal operation parameters through external interface. The configuration interfaces are RS485 and RJ45. The contents of configuration include white list of sensors, information of distribution room, transmission parameters, etc.

All the data will be calculated in collection terminal through data processing logic. Date from the scattered voltage terminal shall be coupled with that from current terminal according to the configuration of the coupling relationship. Then, the three-phase voltage and current date from the same outgoing or incoming line will be storage and analysed together. At last, the power quality characteristics based on three-phase data will be calculated, such as current three-phase imbalance, phase difference, power, etc. All data will be packaged and stored according to the requirements of PQDIF file. Its processing logic is shown in figure 7.

![Figure 7. Digital signal logic of data collection terminal.](image)

4. Test

The power quality monitoring system of distribution room developed in this paper was installed on the outgoing side of a distribution room in a community. The scene diagram is shown in figure 8. The real-time current and power quality data can be obtained by backstage monitoring, as shown in figure 9. This monitoring system has realized the established function

![Figure 8. Monitoring system test.](image)

5. Conclusion

In this paper, a new power quality monitoring system is developed to solve the problem of power quality in distribution room. This system is composed of three kinds of terminals which are current quality terminal, voltage quality terminal and power quality data collection terminal. In order to install this system rapidly and easily, new sensor technology, wireless communication technology and the
coil energy acquisition technology are developed. At last, this system has been tested and realized the established function

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