Community Power Monitoring and Management System Based on LabVIEW

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Abstract. With the wide application of power equipment and non-linear equipment in the community, the power quality of the power grid is further reduced. Therefore, power quality has become the research focus of the power industry today. This paper designs a community power monitoring and management system based on LabVIEW. The system consists of two parts: data acquisition circuit and software program. The specific functions include the communication configuration of LabVIEW and data acquisition card and the design of power quality monitoring. The feasibility of the power monitoring and management system.

1. Calculation and analysis of electrical energy indicators

1.1 Calculation and analysis of power supply voltage deviation
The supply voltage deviation refers to the difference between the actual measured voltage rms value and the system rated voltage value. The final voltage deviation value is expressed as a percentage. The calculation formula is:

$$\Delta U = \frac{U - U_N}{U_N} \times 100\%$$

(1)

In the above formula, \(U\) is the measured voltage and \(U_N\) is the system nominal voltage. Voltage deviation is one of the most important indicators to pay attention to when studying power quality. In power systems, system reactive power is insufficient, power transmission distance is too long, system reactive power compensation is excessive, system load is too light or too heavy. Can cause deviation of the supply voltage. Among the above reasons, the lack of reactive power in the power grid is the most important cause of voltage deviation in the network[1].

1.2 Calculation and analysis of frequency deviation
The frequency deviation refers to the difference between the actually measured frequency and the rated frequency. Calculation formula:

$$\Delta f = f - f_0$$

(2)

In the formula, \(f\) is the measured frequency and \(f_0\) is the rated frequency.

Frequency deviation is an important indicator of power quality. Whether the power system operates at high or low frequencies will have a great impact on power companies and power plants. Changes in frequency will cause unstable speeds in various motors, which will affect the quality of the products.
produced by the company. Due to the large number of impact loads and rectification equipment in the power system, this will cause the power to deviate from the initial state\(^2\).

1.3 Calculation and analysis of power and power factor

(1) Single-phase circuit

In a single-phase circuit, the active power \(P\) is also generally called average power, actual power or real power, which indicates the effective power of the load during actual operation. Its expression:

\[
P = \frac{1}{T} \int_{t_0}^{t_0 + T} u(t)i(t) \, dt
\]

(3)

Where \(u(t)\), \(i(t)\) are the instantaneous values of the voltage and current at the time \(t\) of the phase circuit, respectively, so \(p(t)\) is the instantaneous power of the phase circuit at time \(t\). Similarly, the process of discretizing its sampling point to \(N\) is as follows:

\[
P = \frac{1}{T} \sum_{k=1}^{N} u_k i_k \Delta t = \frac{1}{N} \sum_{k=1}^{N} u_k i_k
\]

(4)

For a single-phase sinusoidal circuit, the active power can be defined as:

\[
P = UI \cos \varphi = S \cos \varphi
\]

(5)

In the above formula, \(U\) and \(I\) are respectively the voltage rms value and the current rms value of the phase circuit, and the product of \(U\) and \(I\) is its apparent power \(S\), and \(\varphi\) is the phase angle of the current lag voltage in the phase circuit, that is, the power factor angle. It is easy to derive the calculation formula of the power factor \(\cos \varphi\) of the phase circuit as

\[
\cos \varphi = \frac{P}{S}
\]

(6)

Then the calculation formula of the reactive power \(Q\) of the single-phase sinusoidal circuit is:

\[
Q = UI \sin \varphi
\]

(7)

(2) Three-phase circuit

In a three-phase symmetrical circuit, the three-phase total active power can be calculated by multiplying the active power of any one of the three phases by three. In the actual three-phase circuit, since the load connected by the three phases is not necessarily symmetrical, the system will calculate the three-phase total active power according to formula (8). That is, calculate the active power of the three phases and add them separately.

\[
P_{\text{total}} = P_A + P_B + P_C = \frac{1}{N} \left( \sum_{k=1}^{N} u_{kA}i_{kA} + \sum_{k=1}^{N} u_{kB}i_{kB} + \sum_{k=1}^{N} u_{kC}i_{kC} \right)
\]

(8)

Similarly, the total apparent power of the three-phase circuit is the sum of the three-phase apparent power of \(A\), \(B\), \(C\), as shown below:

\[
S_{\text{total}} = U_{A}I_{A} + U_{B}I_{B} + U_{C}I_{C}
\]

(9)

By combining equations (8) and (9), the total power factor \(\cos \alpha\) of the three-phase circuit can be derived as:

\[
\cos \alpha = \frac{P_{\text{total}}}{S_{\text{total}}}
\]

(10)

1.4 Calculation and Analysis of Voltage Qualification Rate and Power Supply Reliability Rate

For urban areas: the reliability of power supply is not less than 99.90%, and the pass rate of residential customers is not less than 96%. For rural areas: the reliability of power supply is not less than 99.589%, and the pass rate of residential customers is not lower than 93.89%.

(1) The voltage pass rate refers to the percentage of the total time of the monitoring point voltage within the qualified range and the total time of the monthly voltage monitoring within one month of
the grid operation. The voltage monitoring point should select a representative substation 10kV bus and user as the voltage quality assessment point. For low voltage (380/220) users, the monitoring point should be set at the head end of the representative low voltage line and end. The calculation formula is as shown in equation (11)[3].

\[
\text{voltage pass rate(\%)=}\frac{\text{voltage qualified time}}{\text{assessment time}}\times 100\%
\]  

(2) During the statistical period, the power supply reliability rate (RS-3) does not account for the need to limit the power due to insufficient system power. The calculation formula is as shown in equation (11)[4].

\[
\text{power supply reliability(\%)=}(1-\frac{\text{power outage time}}{\text{statistics time}})\times 100\%
\]  

2. System software and hardware design

A virtual instrument is an instrument that is tightly integrated with a computer. Virtual instruments offer greater scalability and flexibility than traditional instruments. As a standard data acquisition and instrument control software, LabVIEW is widely accepted by academia, industry and research laboratories[5].

In the virtual instrument technology, the main function of the hardware module is to convert various analog quantities (current, current, liquid level, water temperature, pressure and other physical quantities) and some digital quantities input by the outside world into a suitable hardware system through a certain hardware system. The main hardware modules of the power monitoring and management system designed in this paper include: three-phase voltage sensor, three-phase current sensor, data acquisition card and computer.

Due to the large electric load of the residential area, air conditioning in the residential area is a high-power load, especially in the summer, air conditioning is the main cause of overloading of the power system. Therefore, the load selected in this experiment is Gree's split cold air type floor air conditioner(KF-120LW/E(12368L)A1-N2). The performance indicators of air conditioners are shown in Table 1.

| Table 1. Performance indicators of air conditioning |
|-----------------------------------------------|
| **index** | **parameter** |
| Cooling capacity | 1200W |
| Rated voltage | 380V 3N~ |
| Rated frequency | 50Hz |
| cooling rated frequency | 336W |
| exhaust side maximum working pressure | 2.5MPa |
| suction side maximum working pressure | 0.6MPa |

The acquisition circuit consists of three voltage transformers, three current transformers and a data acquisition card. The specific experimental wiring is shown in Figure 1.
3. Power Monitoring and Management Platform

3.1 Data acquisition card collection and analysis
Data collection is collected by the acquisition card, and the collected data is written into the queue. This queue uses the cyclic producer consumer model[6]. This block diagram is the producer. In this data block diagram, the data error cluster can be transmitted and displayed, and the text problem is displayed. When the loop stops collecting, the data queue is released. The block diagram of the data acquisition program is shown in Figure 2.

![Data acquisition block diagram](image)

**Figure 2.** Data acquisition block diagram

The block diagram is based on the data information generated by the producer, and the data is parsed for analysis. This cycle is the consumer of the previous data producer. The block diagram is the producer of the next producer consumer, and the data is passed to the next. The consumer calculates the average value of the collected data, then performs a proportional operation and multiplies the corresponding scale factor to obtain the corresponding data information value. The data analysis program block diagram is shown in Figure 3.
3.2 real-time acquisition interface

The main acquisition parameters of the real-time acquisition interface include three-phase voltage values and three-phase current values. Therefore, when designing the front panel, you need to select the “meter” in “new” in the “Control” panel, which are named “A phase voltage effective value”, “B phase voltage effective value”, “C phase voltage effective value”, “A phase current effective value”, “B phase current effective value”, “C phase current effective value”. The front panel of the real-time acquisition interface is shown in Figure 4.

Figure 4. Real-time acquisition interface front panel

The basic parameters include voltage and current, frequency, power, electrical, and imbalance analysis for each phase. Therefore, when designing the front panel, you need to select the “numeric display control” in “New” in the “Control” panel, arrange these functions according to the corresponding needs, and select “New” in the “Control” panel. Therefore, the design of the front panel of the basic parameter module is completed. The front panel of the basic parameter module is shown in Figure 5.
3.3 Comprehensive record

The comprehensive record includes the storage of measurement data, the recording of the power-off time, the reliability of the power supply, the time of the deadline, the phase loss time, the pass rate, and the hourly record. When designing the front panel, you need to select the “Numerical Display Controls” in the “Controls” panel, which are named as the upper limit time, the lower limit time, the phase loss time, the total time, the pass rate, the power outage time and the power supply reliability[7]. The front panel of the comprehensive record is shown in Figure 6.

The system will record the total time of the collection in real time, using the time format string, and then processing the time and date string, and extracting the day string to judge. When the current date is different, the data information will be stored. The storage block diagram is shown in Figure 7.
4. Conclusion
This paper first introduces the measurement and calculation methods of various indicators of power monitoring and management, then describes the hardware design of the system and the characteristics of the LabVIEW software platform, and uses LabVIEW to write the program for communication with the data acquisition card, and then writes the power monitoring and management system. Each parameter measurement module and management module includes real-time acquisition interface module, basic parameter module and integrated recording module. Finally, each sub-module is connected together, and the design of the community electric energy monitoring and management system is completed through the acquisition circuit.

5. References
[1] Wang M, Sun Y A practical, precise method for frequency tracking and phasor estimation[J]. Power Delivery, IEEE Transactions on, 2004, 19(4):1547-1552.
[2] Liu Xingyuan. Factors affecting power quality and improvement measures [J]. Science and Technology Information, 2013 (15): 401 + 466.
[3] Liu Tingting. Design and implementation of voltage monitoring and integrated management system of Meishan Company [D]. University of Electronic Science and Technology, 2013.
[4] Wang Ruiping,Liu Xiaohui,Zhang Zhong,Qian Zhenyu.Application of Voltage and Current Real-time Monitoring Device in Railway Battlefield Power Supply[J].Electric Railway,2017,28(06):13-15.
[5] Elliott C,Vijayakumar V, Zink W, et al. National Instruments LabVIEW: A Programming Environment for Laboratory Automation and Measurement[J]. Journal of the Association for Laboratory Automation, 2007, 12(1):17-24.
[6] Wu Ruidong. Distributed optical fiber vibration detection and positioning system based on linear Sagnac [D]. Taiyuan University of Technology, 2017.
[7] Li Guodong. Research on Modern Power Quality Comprehensive Evaluation Method [D]. North China Electric Power University (Beijing), 2010.