Power Quality Monitoring and Energy Efficiency Management of Microgrid based on wind-PV-ES Hybrid System

Guanlu Yang, Minxu Wu, Yang Wang and Zehong Huang

College of Information and Science Engineering, Huaqiao University, Xiamen, China
E-mail:979576109@qq.com

Abstract. With the vigorous development of new energy power generation technology, the use of a large number of power electronic components and non-linear loads seriously threatens the power quality of microgrid systems. Therefore, it is necessary to monitor the power quality parameters Therefore, it is necessary to monitor the power quality parameters during its operation in real time so as to maximize the use of energy resources. This article focuses on the overall design of the microgrid power quality monitoring system. In the hardware design part, this paper uses two chips of DSP and FPGA to collect, process and analyze the signals of the power grid. Mainly includes the system overall design idea, the signal conditioning module design, the digital signal processing circuit, the communication port circuit and so on. Based on this, combined with the virtual instrument technology, designed and completed a micro-grid power quality inspection platform based on Labview.This paper also establishes the reactive power compensation scheme of the microgrid TSC system by using Matlab/Simulink software, further improves the power quality and power factor of the operation, and verifies the power quality improvement scheme of the microgrid through simulation.

1. Introduction

At this stage, distributed generation can be divided into two main types: one is a photovoltaic power generation system; the other is a wind power generation system. Under the current state of energy demand and environmental protection in our country's current economic development, as a very effective supplement to the large power grid, the development of microgrids has great potential [1]. Today, although Distributed generation and microgrid technology have received increasing attention in many countries, they are mainly in the equipment development and control of microgrid systems, most of the research on core technologies related to energy efficiency management and grid-connected operation stability of microgrids is in its infancy. Therefore, the in-depth study of the microgrid system can lay a solid foundation for the development of China's micro-grid and has a very important engineering application value [2].

2. Design of power quality monitoring system based on FPGA and DSP

2.1. Overall system design

This article aims at the power system's requirements for the power quality analyzer, and designs a power quality monitoring and analysis system based on DSP and FPGA.The DSP chip, also known as the digital signal processor, is a microprocessor that is particularly suitable for digital signal processing operations. Its main application is to implement various digital signal processing algorithms in real time and quickly. FPGA is a product of further development based on programmable devices such as PAL, GAL, and CPLD. It emerged as a semi-custom circuit in the field of application specific integrated circuits (ASIC), which not only solves the shortcomings of the custom circuit, but also overcomes the shortcomings of the limited number of original programmable device gates. The designed system is composed of a DSP28335 minimum system board and a FPGA-based data acquisition board, the data acquisition board can achieve 8 single-ended and 16-bit high-speed synchronous analog signal data acquisition. The system can be divided into three parts: signal conditioning module, data acquisition and processing module and human-machine interface module.

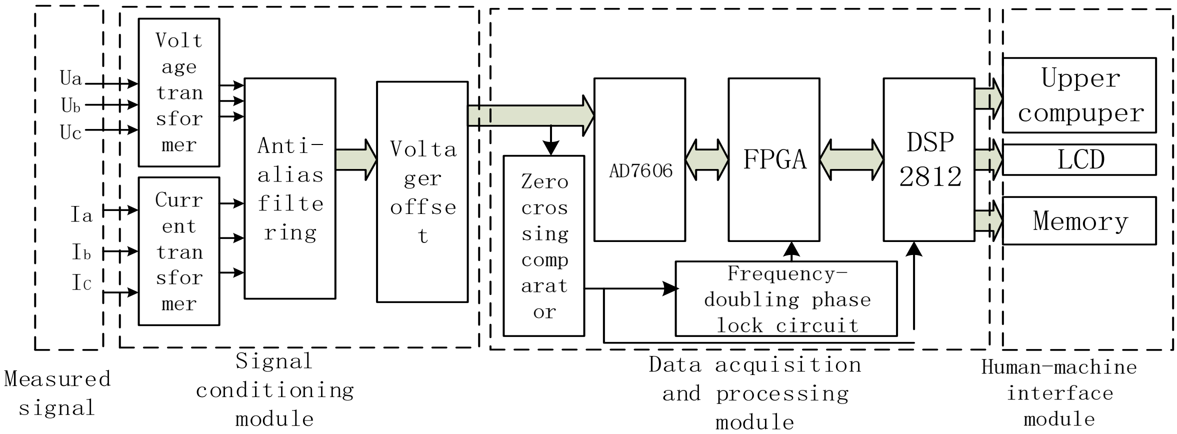

Figure 1. Overall system block diagram

2.2. Signal conditioning module design

In order to achieve high-quality data acquisition and prevent different frequency spectrums from interfering with each other, the design incorporates an anti-aliasing filter based on a second-order filter network. The harmonics required for this analysis are up to 64 times, that is, the highest frequency of harmonics is 3.2kHz. The number of sampling points in the AC voltage signal cycle is 128, so the frequency of the analog-digital sampling chip should be more than twice the maximum frequency of the harmonics, and the sampling frequency of 6.4 kHz is beneficial to prevent spectrum aliasing. Furthermore, in order to enhance the effect of signal recovery, a low-pass filter must be added to the sampling circuit. Considering the actual situation, we chose to set the cut-off frequency of the low-pass filter to 3.5 kHz. This paper designs an active anti-aliasing filter with low delay, low signal attenuation and high noise attenuation based on the OP07AH [3].

2.3. Data acquisition and processing module

2.3.1. AD module selection. This design chose the AD7606 chip instead of the sampling module that comes with the DSP to achieve high-precision, low-latency sampling. This design selects the parallel mode to read the AD7606's AD data and selects an input voltage range of ±5V. The AD7606 chip data port is connected to the IO port of the FPGA. Through FPGA's signal to CONVST, it can control 8 sampling channels at the same time in order to guarantee high precision. And the RD and CS ports of the AD7606 are connected to the FPGA so that the FPGA can better control the sampling chip. Send the RD and CS signals to the AD7606 to read the data on the DB [15:0] pins.

2.3.2. Zero-cross comparison circuit design. In order to provide the back-end circuit with a square-wave signal that is consistent with the grid frequency, a LM393 zero-cross comparison circuit was designed. This circuit provides a frequency reference for the back-end phase-locked loop and the measurement circuit. The working principle of the circuit is that when the input signal is greater than zero, the reverse voltage of the zero-crossing comparison circuit is greater than the voltage in the same direction, so the low-level signal is output, and the circuit can output the voltage signal on the AC side at a high level of 5 V. Convert to a square wave signal with the same frequency and phase.

2.3.3. Digital phase-locked loop circuit. The input side of the phase-locked loop CD4046 is the output square wave signal of the zero-crossing detection circuit, and the synchronous sampling circuit is composed of a CD4046 phase-locked loop chip and a CD4040 binary counter, and the output signal thereof can be used after being multiplied by 128. The circuit guarantees the dynamic characteristics of the output signal. Even if the measured signal changes, it can acquire the corresponding frequency multiplication signal and achieve the function of synchronous sampling.

2.3.4. DSP and FPGA communication interface circuit. This design will configure the FPGA as an external expansion chip of the DSP, send the data collected by the DSP to the FPGA for calculation, and return the result to the DSP. Since the clock frequency of the DSP is about 150M, it will not interfere with the system and the transmission speed is fast, so this solution can be used as a communication solution for power quality monitoring. In order to facilitate the system's debugging and development, the system is configured with an extended RS-232 serial port to communicate and interact with the host computer. The port implements data output, and then the host computer performs image drawing.

3. Design and development of system software design

What this design wants to achieve is to control the AD chip through the FPGA to collect the data of the power system in real time, and then transmit the digital quantity after the AD conversion to the DSP. The data obtained by the analysis is analyzed and processed by the DSP.

3.1. Data acquisition module software design

The software design of the data acquisition module is mainly controlled by the FPGA, which completes the effective sampling and data storage of the data. This data acquisition system uses Verilog HDL language programming.

The system applies parallel sampling to the 6-channel signal. Before each sampling, the FPGA updates the sampling rate according to the command. The collected data is stored in the FIFO code. After the DSP receives the sampling command, it reads it and then uses the relevant electrical parameters. Do the operation. In order to ensure that the read conversion data pointer points to the first data to be converted, the AD7606 must be reset. As long as two CONVST pins (CONVSTA and CONVATB) are connected, the channels can all be set to sample at the same time. Therefore, we can start the rising edge of the shared CONVST signal and sample all the analog input channels at the same time.

3.2. Labview-based PC software building

The main functions of the labview PC set up this time are: the data obtained after DSP acquisition and processing are displayed on the monitoring panel in real time [4], and these data are saved in the Access database for reference and query. When the host computer displays the measurement results, the function module uses a pagination display, a total of six sub-pages, namely: the basic parameters of the power module, power module, three-phase unbalanced module, harmonic module, voltage fluctuation and flicker module and power supply Reliability rate module.

4. Research on microgrid energy efficiency management system

4.1. MATLAB modeling of micro-grid TSC reactive power compensation device

The main circuit of this modeling is composed of wind power and photovoltaic generation with energy storage microgrid system and a reactive power compensation device. The validity of this model can be verified by comparing the various states before and after the reactive power compensation of the microgrid. The device simulation mainly includes the following parts: wind power generation module, photovoltaic power generation module, load module, microgrid grid-connected controller module, TSC module, and reactive power compensation control module [5]. In this design, a model of wind power storage and microgrid grid-connected power generation is first built. Firstly, the voltage and current on the line are detected, and then the active power and reactive power on the line are calculated by a power detection module, and then the controller Calculate the reactive power to calculate the capacitor bank that needs to be switched, and then switch through the TSC system.

4.2. Simulation analysis

The main purpose of the reactive power compensator built in this paper is to compensate for the reactive power required for the operation of the microgrid. When the reactive power of the load changes, the system can compensate the reactive power in the system by switching the capacitor bank.

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Power, so that the power generated by the microgrid can be maximized. In order to observe the effect of the reactive power compensation of this design, we established the three-phase controllable load and control the reactive power of the load. The simulation waveform is as follows:

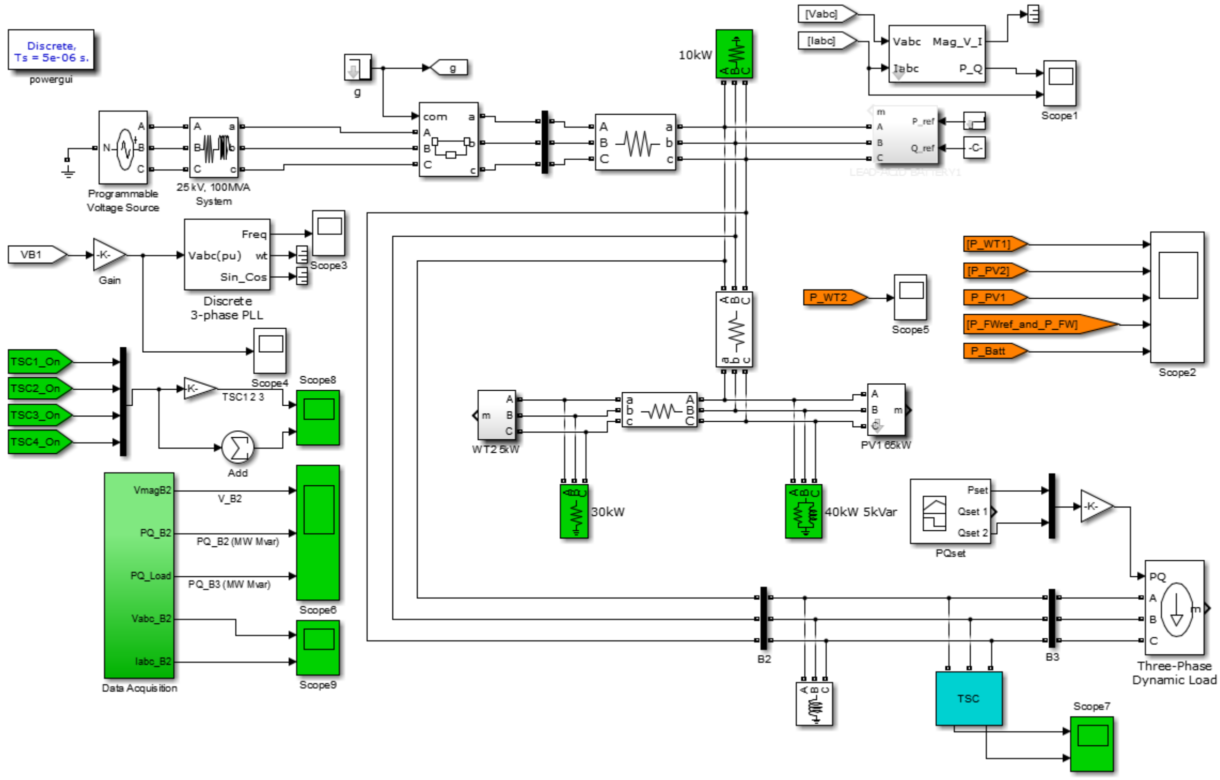

Figure 2. System Simulation

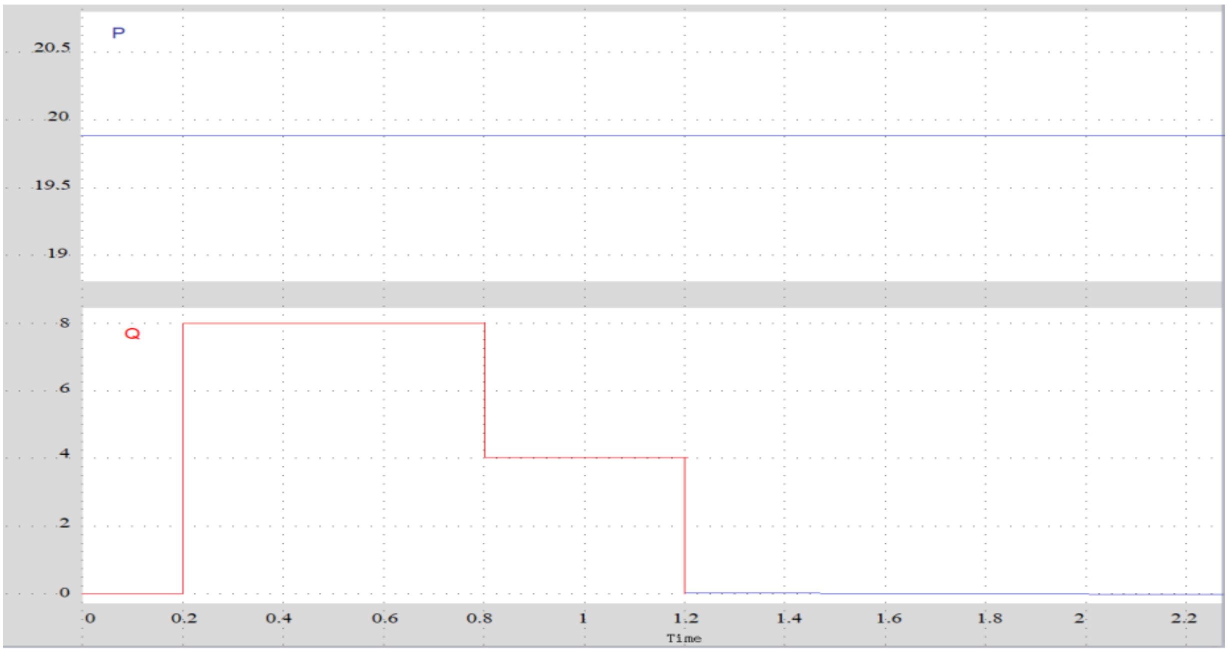

Figure 3. Reactive power curve of the load

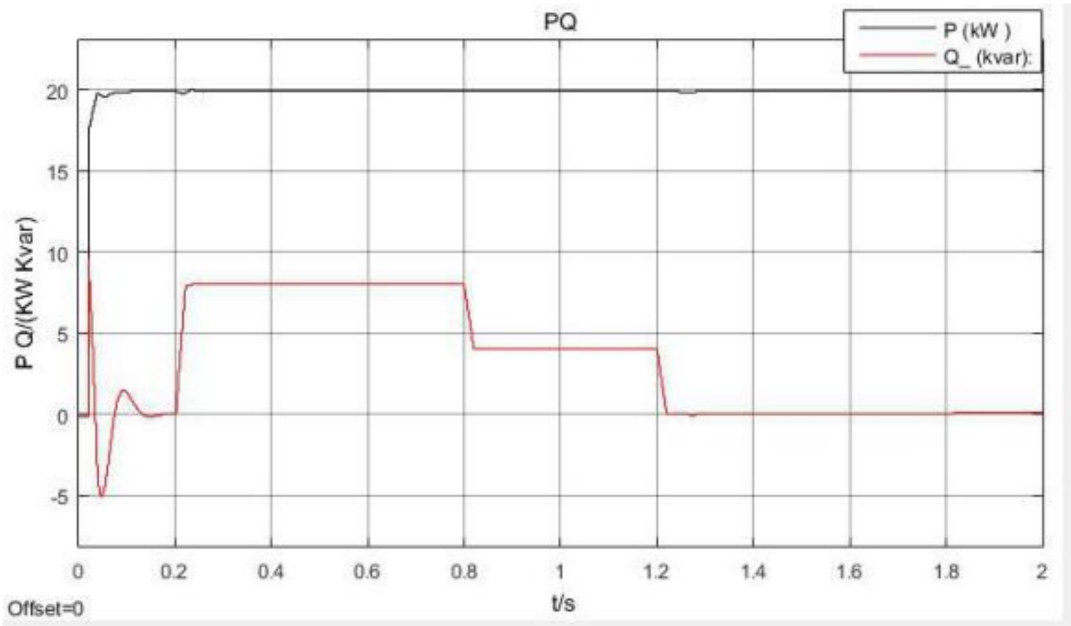

Figure 4. Waveforms of active and reactive power

When we change the reactive power of the load from 0 to 8 kvar at 0.2 s, after 0.02 seconds, the active and reactive power in the system fluctuate drastically. When the reactive power compensation device is input, the voltage lags after 0.02 seconds. For stability, the reactive power in the line is significantly increased and harmonics in the circuit are effectively suppressed. It proves that this device can effectively improve the microgrid power quality.

5. Experiments and analysis

In this design, a small stand-alone wind and light storage microgrid system was actually built on the building platform. The experimental system is mainly composed of a wind turbine (300W) and a photovoltaic panel (50W× 4), battery, inverter equipment and other components. The load is 3 23W energy-saving lamps.

The microgrid power quality monitoring system designed this time is applied to the stand-alone wind and solar storage microgrid built above. The following is the microgrid operational data obtained through the monitoring system. Since there are many parameters for this monitoring, this data only lists the A-phase power quality parameters.

From the above, we can see that this system can accurately monitor the power quality of the microgrid system. Through the obtained data, it can be proved that the independently constructed wind and solar storage microgrids actually built this time meet the national standards and can be operated stably.

Table 1. A-phase frequency data table

Number of measurements	A-phase frequency (HZ)	Frequency deviation (HZ)
1	50.02	0.02
2	50.02	0.02
3	49.99	0.01
4	49.98	0.02
5	50.01	0.01

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Table 2. Voltage and current rms data sheet

Number of measurements	A-phase voltage (V)	A-phase current (A)
1	221.5	0.574
2	221.3	0.569
3	221.4	0.584
4	221.7	0.604
5	221.9	0.583

Table 3. A-phase active power and reactive power data sheet

Number of measurements	Active power (W)	Reactive power（VA）	Power factor
1	57.75	113.31	0.454
2	58.57	126.15	0.464
3	58.97	115.39	0.455
4	55.91	119.05	0.592
5	58.82	115.47	0.453

Table 4. A-phase voltage and current distortion rates

Number of measurements	Voltage distortion rate (%)	Current distortion rate (%)
1	1.067	89.861
2	0.987	92.894
3	1.174	83.113
4	1.092	91.132
5	1.174	85.000

6. Conclusions

This article focuses on the hardware and software design ideas of this system. The overall design of the power quality detector is introduced in detail. The system is divided into multiple sub-modules and each module is elaborated. Then the specific flow chart of the sub-modules of the lower computer software system is introduced. The design of the upper computer based on LabVIEW is completed, real-time communication with the lower computer can be realized. The simulation diagram of the reactive power compensation device is constructed by Matlab, and the reactive power compensation device can be obtained through simulation, which can effectively improve the power quality of the micro grid.

7. References

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Acknowledgments

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