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THE RESEARCH OF A SYNCHRONIZED MEASUREMENT SYSTEM BASED ON POWER LINE CARRIER COMMUNICATION

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Abstract. *The paper utilizes the power line carrier to establish a synchronized measurement system. The system includes a host computer, an electrical detection module, a speed detection module, and a control module. Besides sending out the synchronous signal, the host computer also can command the control module to operate the electrical equipment, can collect measured waveforms from detection modules, and can analyze these data. The detection modules are a digital signal recorder, which can monitor real-time waveforms and send them to the host computer. The electrical-signal detection module can measure voltage and current waveforms, and the speed detection module can measure the speed waveform. The control module receives the command of the host computer via the power line carrier, and controls the electrical equipment. Detection and control modules are completed by the AVR chip and its peripheral for specific functions. The communication of the host computer and modules is accomplished by the power line carrier. Detection modules and control modules can be distributed in different regions, and run their functions simultaneously. In the factory, by simply being plugged in, the host computer can fully understand the system status, and remotely monitor and control the electrical equipment anywhere. This paper monitors the motor control works as the object of the application. It will verify that the system has practical applications with complete measurements, simple, easy provisioning and other features.*
Keywords: Synchronized measurement, Power line carrier, Microprocessor

1. **Introduction.** In a large-scale system, the devices disperse at different locations. A single instrument cannot simultaneously directly measure all signals.

This technical limitation makes the measurement of large-scale systems difficult to reach. For acquiring operating data simultaneously in a large-scale system, synchronous measurement technology was developed. For synchronous measurement using synchronous signal as the time reference, the time bases of all the controllers and detectors are able to identically form this time reference, and the problem of synchronization amount measured data can be solved [1]. In the synchronous measurement system, the instantaneous value can be obtained from each meter while the reference times are decided by the synchronous signal, and then the whole system state will be analyzed and understood. The measured data can be transmitted instantly to reach the effect of measurement for a large-scale system. This technique is called a "wide-area measurement". The synchronous measurement system can acquire the whole system state at the same time, as the time errors are shorter than one microsecond. This technology has quite a few advantages in transient phenomena analysis, such as: power system state estimation, stability control, protection technology, transmission line protection relay, and transmission line fault location [2].

The purpose of this paper is to establish a synchronization measurement system. This system includes a host computer, an electrical detection module, a speed detection module, and a control module. The host computer can process the synchronization signal emission, control commands, data collection, and analysis. Besides synchronizing the system, the host computer can command the control module to operate the electrical equipment, can collect measured waveforms from detection modules, and can analyze these data. The LabVIEW graphical interface is used as the operation screen [3]. Via LabVIEW graphical panel of the computer screen, the operation will be simpler and more straightforward. The host computer can send a sync signal; the detector and controller will receive the signal simultaneously. Detection modules and control modules can be distributed in different regions, and synchronously execute control and measurement tasks. Because the distance is very close, the signal decoding times and related processing times are identical. All actions of the detector and controller can be regarded as synchronized. The controllers are used to operate the equipment, as they switch the equipment simultaneously when receiving the synchronous signal. Detection modules are the digital signal-recording device; they can measure the operating signals, including voltage, current, and speed. They also have external communication interface, which can send the measured data to the host computer. The electrical detection module can measure the instantaneous values of voltage and current, while the speed detection module can measure the instantaneous values of a rotor speed, and this information is transmitted via power line carrier. Wherever the host computer is, with being plugged in, the host computer can fully understand the system status and remotely control the electrical equipment [4].

2. **System Establishment.** For the importance of synchronized measurements in the smart grid, this paper uses a host computer, detection modules, and control modules to establish synchronous measurement system architecture, shown in Figure 1. The actual measurement points are dispersed in the field. The system integrates functions of monitor and control via the power line carrier communication. Detailed planning of the modules is described below.

The host computer is used as a synchronous signal source; it can transmit control commands, collect data, and analyze them. Moreover, the purposes of synchronous monitoring and control will be achieved. Interface of the host computer is accomplished by the man-machine interface, LabVIEW; its features include data processing and data analysis.

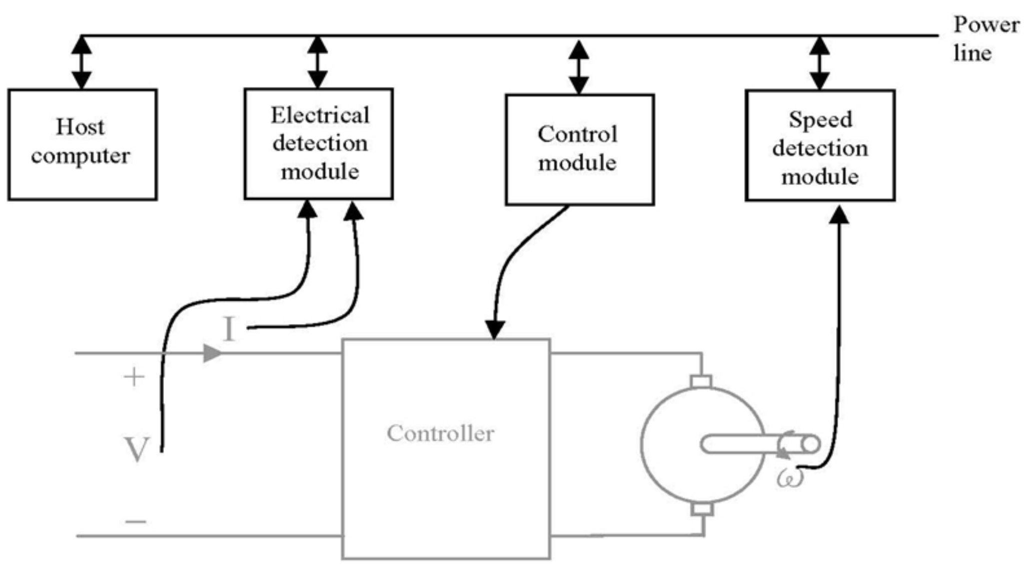

FIGURE 1. Synchronous measurement

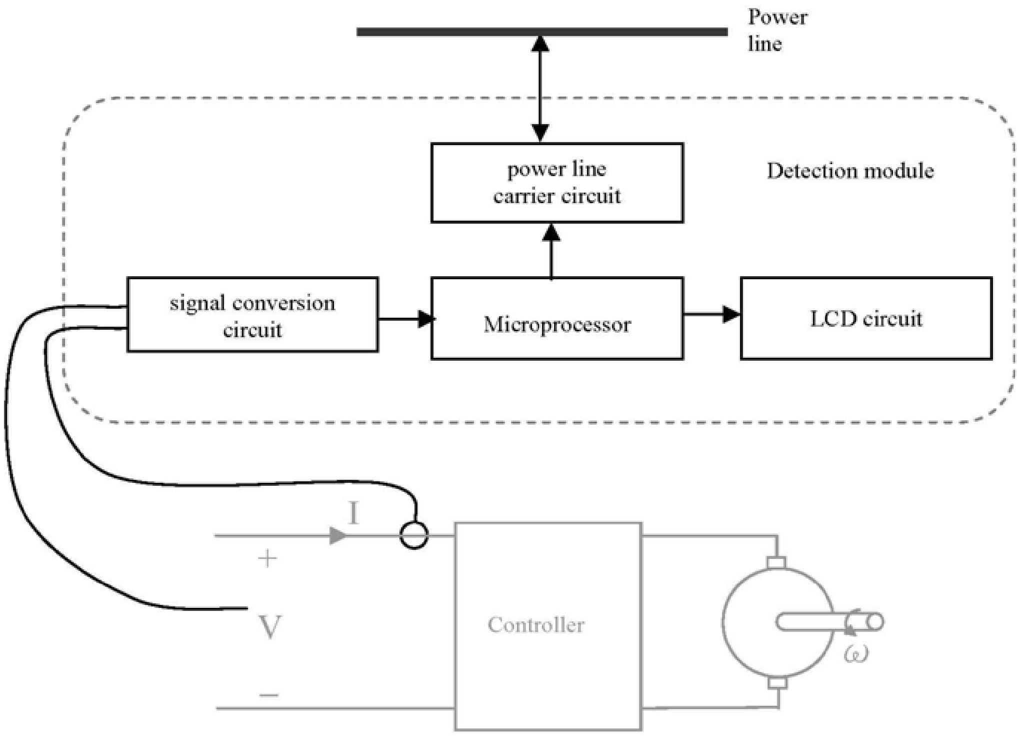

Figure 2. Detection module

The detection module architecture is shown in Figure 2. The detection module records instantaneous data, and sends them to the host computer. The detection module can measure operating signals, including voltage, current, and speed. Measured data can be transmitted through the power line to the host computer for further processing. The detection modules consist of a signal conversion circuit, AVR microprocessor, LCD circuit and power line carrier circuit. In the electrical signal detection module, the signal conversion circuit converts the actual voltage/current to the voltage level that the analog/digital converter can sample. In the speed detection module, the signal conversion circuit converts the pulse to the corresponding speed. The AVR microprocessor can sample the continuous signal, convert the pulse signal, process these data, transmit data, and show the result to the LCD. The LCD can display the waveform and measured value and so on. The purpose of the power line carrier circuit is to modulate data to the carrier signal and transmit such data to the host computer via the power line.

The control module architecture is shown in Figure 3. Control modules can switch the equipment according to the host computer command. Control modules consist of the AVR microprocessor, LCD circuit, and power line carrier circuit. The AVR microprocessor can output result to the LCD circuit and order the switch to action. The LCD circuit can display switch states. The purpose of the power line carrier circuit is to convey the command of the host computer and return the switch state of the control module.

The system can operate in the range where the power line covers. The synchronous measurement system has been accomplished by the Internet function of the power line carrier.

3. Results and Discussion.

3.1. **System functions.** This paper uses the host computer, a control module, an electrical detection module, a speed detection module, and a controlled device to construct a synchronous measurement system, shown in Figure 4. The host computer and periphery are integrated by power line carrier communication technology. Each module can control or detect independently. They also can be integrated into a synchronous measurement

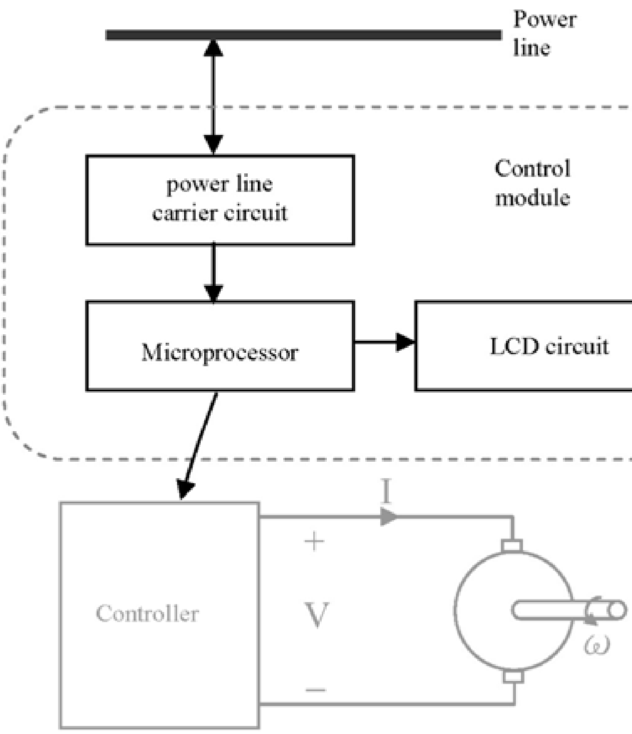

FIGURE 3. Control module

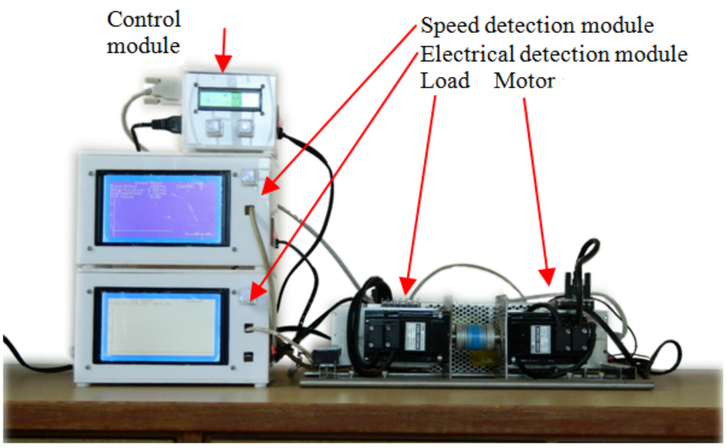

FIGURE 4. Practical system

system via connection of the power line. The system can operate in the range where the power line covers. The synchronous measurement system has been accomplished by the Internet function of the power line carrier. Detailed functions of each module are as follows.

(1) Control module: Control module can field control the equipment ON/OFF. In this paper, an AC servomotor is taken as the equipment, and the default speed is set at 500 rpm. The control module can also connect with the host computer through power lines to achieve remote control. The host computer controls the AC server motor with the control module, including start, stop, speed change, or K_p, K_i change.

(2) Electrical detection module: Electrical detection module can monitor real-time waveforms, including the instantaneous values of the voltage and currents. The detector is also a digital signal recorder. Measured data can be transmitted through power lines to the host computer for further processing.

(3) Speed detection module: Speed detection module measures the pulse signal from the motor's encoder. This module calculates the real speed by the interrupt program; the display includes instantaneous value, average speed, vibration, and spectrum of vibration [5]. The measured data can be transmitted through power lines to the host computer for further processing.

(4) Host computer: The host computer is accomplished with a terminal program, as shown in Figure 5. The program allows the host computer to control the driver directly through the power line carrier. It commands the driver to start, stop, or change the parameters instantly. The program can acquire measured data from the electrical detection module and the speed detection module. When receiving the synchronous signal, all detection modules start to sample data for two seconds with a 128 s/sec sampling rate.

The system integrates functions of monitor and control via the power line carrier communication.

3.2. **Synchronous measurement.** This section describes the synchronous measurement functions of this system with a dynamic measurement example. The host computer sends synchronous signal to all modules; when receiving the synchronous signal, all modules start to control or the detect tasks. In this case, the control module commands the motor to start from still to 500 rpm. When receiving the synchronous signal, the electrical

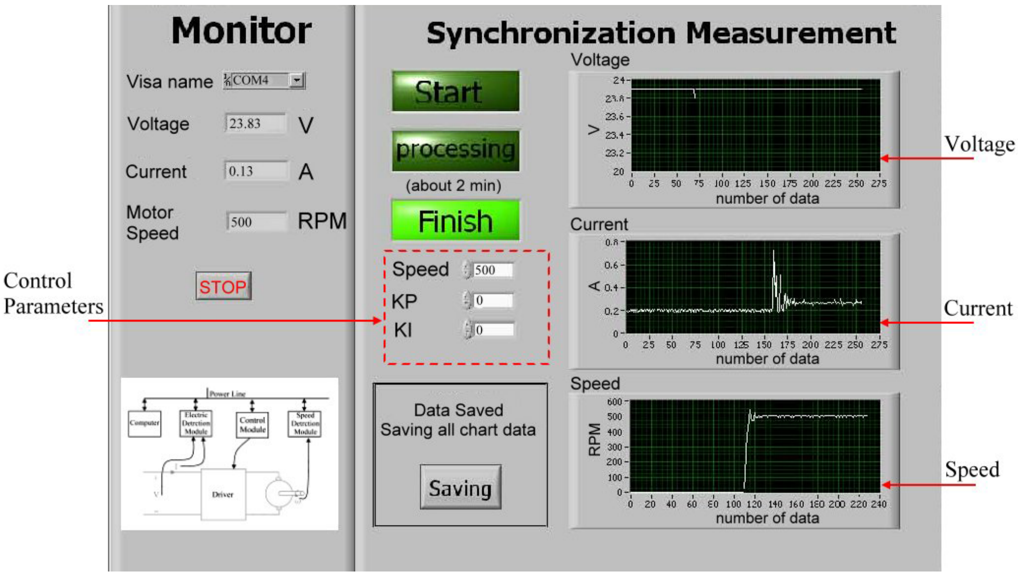

FIGURE 5. Screen of host computer

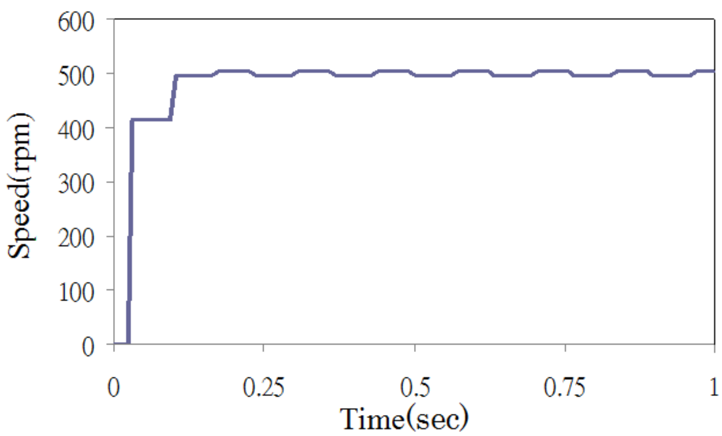

FIGURE 6. Speed of motor

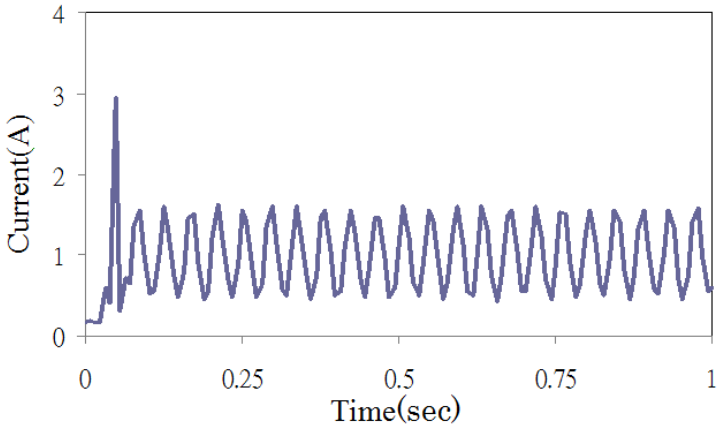

FIGURE 7. Current of motor

detection and speed detection modules start to sample data for two seconds with a 128 s/sec sampling rate. The electrical detection module can record the instantaneous value of the voltage, current, and show the current waveform. The speed detection module can display the instantaneous speed, average speed, motor vibration and shows speed chart and vibration spectrum. The measured data of speed and current are shown in Figures 6 and 7. In this case, due to the unbalanced load, an obvious oscillation of current will be caused. These data in the host computer have been synchronized. In this case, this system can simultaneously acquire transient responses from different modules. These data will provide information for a follow-up study to explore.

The effective transmitted distance between two points for PLC modules is about 200 M in field test. However, under the heavy load condition, the transmitted distance of PLC modules can only reach about 30 M. The line impedance could drop drastically and highly reduce the carrier signal. The walls seriously affecting the quality of wireless transmission in a home or office environment, PLC will undoubtedly become one of the best solutions of data transmission in these fields.

4. **Conclusions.**

This paper accomplishes a synchronous measurement system, including a host computer, two detection modules, and a control module.

The host computer not only acquires measured data from detection modules, but also sends commands to the control module for operating equipment. The host computer can send a synchronization signal, which is simultaneously received for all modules. The host computer can also record measured data of voltage, current, and speed. The electrical signal detector can measure instantaneous data of voltage and current. The speed detector can measure the speed data and record the dynamic signals. The detection modules measure instantaneous waveforms, and send them to the host computer via the power line. The control module can execute tasks based on commands from the host computer. Each part of the modules is as below.

(1) Signal converting circuit: This circuit makes the voltage, current and pulse to meet the input specifications of the microprocessor.

(2) Microprocessor: It can sample continuous signal or pulse, output results to the host computer, display the operation status to LCD, and command the controller to action.

(3) Power control circuit: This circuit can control equipment according to the command.

(4) Power line carrier circuits: This circuit connects detection modules and the host computer as a communication network.

These modules can be increased or decreased in response to different demands, which are flexible and highly scalable. In short, this paper uses the power line carrier to establish a synchronization measurement system. Users can easily construct the architecture, which can also monitor industrial electrical equipment. The future can be integrated Wi-Fi, Zigbee and other communications technology, which makes the system more complete and robust.

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