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# ESTABLISHING THE SMART GRID OF THE HOME AREA NETWORK BY POWER LINE CARRIER

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Abstract. *The paper establishes the smart grid of the home area network by power line carrier. The system includes a host computer, several detection modules, and several control modules. The particular function of each module is completed by a microprocessor and peripheral. The operation screen of the host computer is accomplished by a man-machine interface of LabVIEW. By graphical screen panel operation of the LabVIEW, the operation will be more simple and straightforward. The host computer not only can control electrical equipment by ordering the control module, but can also acquire measured data from detection modules and process these data. The detection modules are digital meters, which can monitor the bus voltage and branch current. This module also has the communications interface to send measured data to the host computer. Control module can switch the electrical equipment by local control or by remote control of the host computer via the power line carrier. The communication of inter-module is linked by the power line carrier. In the building, simply by being plugged in, the host computer will monitor and control the electrical equipment anywhere.*
**Keywords:** Smart grid, Power line carrier, Home area network

1. **Introduction.** In recent years, countries have made much effort to reduce energy consumption of the earth and reduce greenhouse gas emissions. For arousing awareness of energy conservation, appropriate energy management is the basic condition. The best way of appropriate energy management is to set up smart grid systems. The so-called "smart grid" uses information and communications technology to detect and collect power condition of the supply side. Then, the system adjusts the power distribution or power consumption, which achieves energy savings or loss reduction.

A smart grid includes power transmission and distribution network, advanced metering infrastructure, energy storage equipment, information management software, and circuit protection. According to distance, the smart grid can be classified as local area networks (LAN), interior network of power traders; wide area networks (WAN), network of traders to the consumers; or home area networks (HAN), interior network of the consumers. The concept of HAN implementation includes four respects: smart appliance, Internet communication, service platform, and power saving. For its part, the smart appliance embeds smart chips or sensors into the appliances, which can control the power of televisions, lamps, air conditioners, and other equipment [1]. Power saving is the visualization of power condition or interaction with user in all kinds of information, which can optimize appliance operation. The equipment of HAN covers smart appliance, electric motor charge, power management chip, power management system, human-machine interface,

wireless sensor, wired sensor, and communication module. The use of HAN allows appliances to have communication function. All kinds of equipment can communicate with each other by common protocol of HAN.

HAN implementation takes basic communication equipment as the major way. Currently, the communication technologies include Wi-Fi [2], power line carrier (PLC) [3], ZigBee, and so on [4]. The PLC uses power lines in a low-voltage environment as a communication circuit, so communication is achieved with a low-speed carrier. It is a technology that modulates transmitted signals to the carrier wave, and adds them to the power line through an interface. For the popularization of power usage, power lines fulfill all fields of life and work, and in fact should be the most popularized network in the world. The power line network is ready-made; the user need not break the decoration to set up a new network for Internet access. The use of the power line will simplify all networks, and save wiring fee and time; therefore, it can replace a monitoring circuit, so power line communication technology has the potential for monitoring applications. Especially, power line can show its remarkable effect on old buildings and factories.

In monitoring systems, LabVIEW usually has been a tool of development. LabVIEW can be applied very broadly. Apart from electronics and communications, it can also be applied in chemistry, machinery, medicine, aerospace, industry, and so on. It can process basic instrument control, measurement, signal processing, image analysis, and control motor completely [5]. It can analyze data, transmit data with Excel, and can show data variation via Internet monitoring [6].

From the above-mentioned facts, this paper will establish a smart grid of a home area network by power line carrier. The advantages are as follows: AVR is a cheap and powerful chip, which allows the designer to create a complete monitoring system under economic considerations. The use of power line carrier can save the cost of construction. The interface of LabVIEW on the computer will help the user to easily understand and operate the system. The PC just needs to install LabVIEW, and it can become a controller with monitoring and controlling functions.

The system takes a switch box as the detected object, and takes the electrical equipment as the controlled object. The switch box is taken as the detected object so that the system can detect the complete power system. Several meters can be integrated in a detection module, which can effectively reduce the meter quantity. The host computer not only simultaneously acquires electricity information from detection modules, but can command the control module to act as well. Much manpower and material resources will be saved. The communications among modules are accomplished by the power line carrier, which effectively reduces complexity and technical barriers.

## 2. **Research Method.**

### 2.1. **Smart grid plan.**

A general power system configuration of small factories and homes is shown in gray parts of Figure 1. A smart grid of the home area network will be proposed and established in this paper. The system takes buses or switch boxes as the measured object, and takes electrical equipment as the controlled object. It can detect the entire power systems when the switch boxes are measured. In addition, functions of many meters can be integrated as a detection module, which effectively reduces the quality of the meters. The system includes a host computer, some detection modules and some control modules, shown as the black part of Figure 1. Detection modules monitor voltages of buses and currents of branches, and transmit the measure data to the host computer. Control modules switch equipment according to the commands of the host computer. The host computer not only acquires the power conditions from detection modules but can also order control modules to operate electrical equipment.

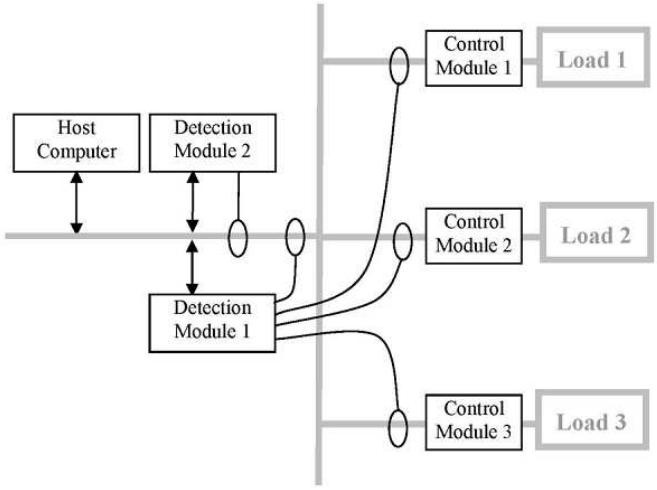


FIGURE 1. The construction smart grid of HAN

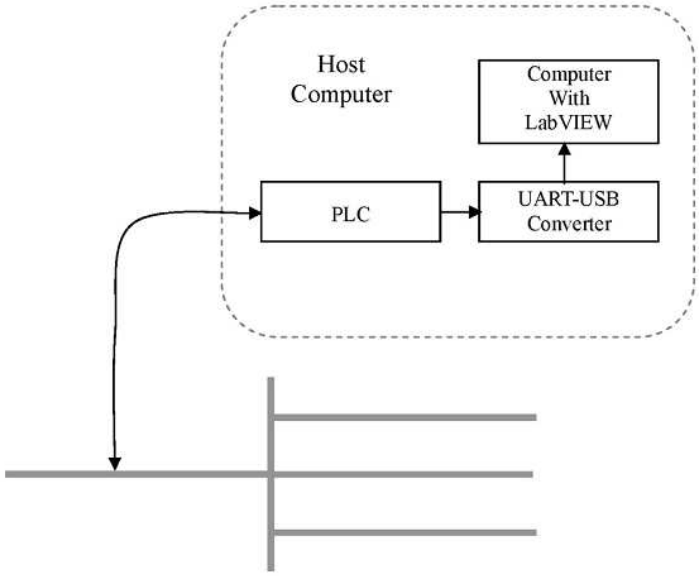


FIGURE 2. Host computer

2.2. **Hardware system.** The system completed in this paper includes host computer, detection module, and control module. Detailed planning of each module is described below. The host computer structure is shown in Figure 2. The host computer can record the measured data from detection modules and command the control module to act.

The host computer includes the man-machine interface, power line carrier circuits, and UART-USB converter circuit. Power line carrier circuits establish communication paths among the host computer, detection modules, and control modules. One end of the power line carrier circuit is the UART port, and the electrical characteristics are the standard of RS232. UART-USB converter circuit can convert the UART interface into the full-speed USB 2.0 interface. After the USB terminal is connected to the host computer, a new port on the LabVIEW interface will be found. The data communication among the host computer and each peripheral module is passed through the port. The host computer can record the measured data from detection modules and command the control module into action.

Structure of the detection module is shown in Figure 3. It can measure real-time power status, including voltage, current, real power, apparent power and power factor. Measured

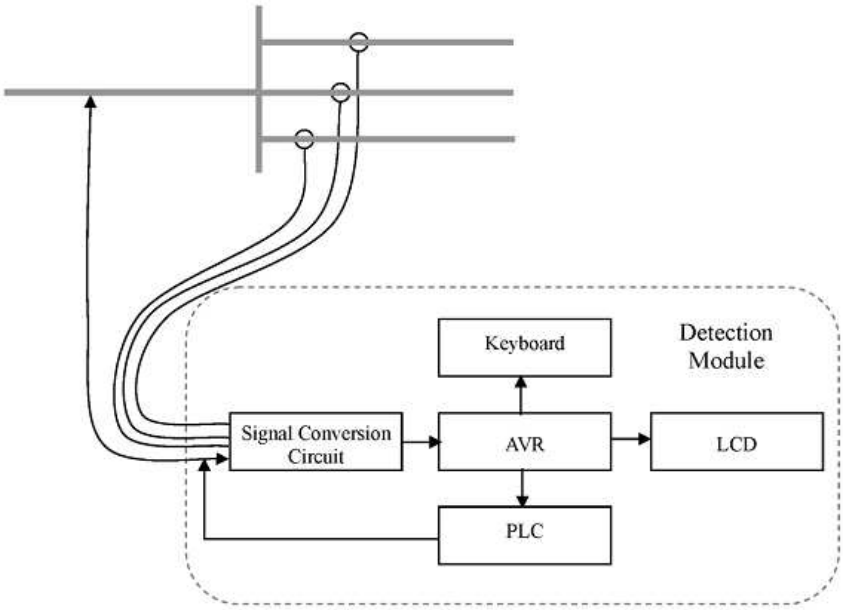


FIGURE 3. Detection module construction

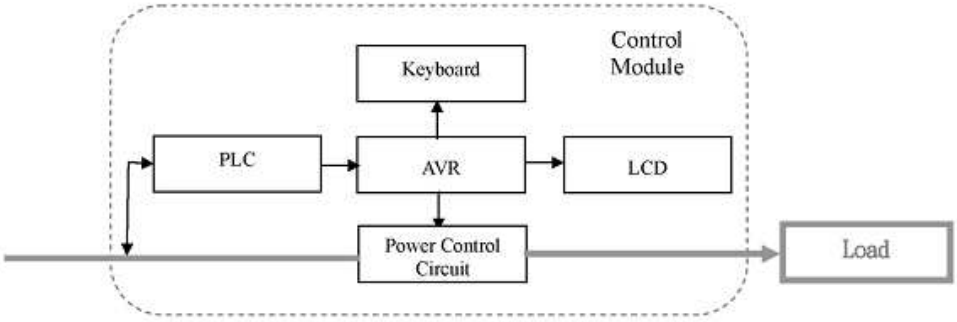


FIGURE 4. Control module

data can also be transmitted to the host computer via the power line for further processing. It consists of signal conversion circuit, AVR microprocessor, keyboard circuit, LCD circuit, and power line carrier circuits. Signal conversion circuit can convert the actual values of voltage and current to comply with the specifications of AVR microprocessor. AVR microprocessor can sample continuous signal, process commands from the computer, and output results to the LCD circuit, which displays measured results. The purpose of the power line carrier circuits is to modulate the measured data to the signal on power line carrier, and transmit the data to the host computer. Structure of the control module is shown in Figure 4. The control module can switch equipment by local control or remote control. The control module consists of an AVR microprocessor, keyboard circuit, LCD circuit, power control circuit, and power line carrier circuits. The AVR microprocessor can process commands from the keyboard and computer, order power control circuit into action, and output results to the LCD. The keyboard circuit can determine the switch status, while the LCD circuit can display switch status. The purpose of the power line carrier circuits is transmitting commands from the host computer and returning switch status of the control module. The system allows the operations in the range where the power line is covered. Using the communication ability of power line carrier, the load management and monitoring system will be established.

2.3. **Power line carrier circuit.** This circuit uses the power line carrier data transmission module (CZ-03) of CAIZHI Technology. CZ-03 is a low cost, high performance

power line carrier module. This module can transmit data through the power line in the low-voltage distribution network. It provides low-speed two-way translation capabilities with a 300bps baud rate. The module is embedded with carrier anti-collision mechanism, and in a certain environment, multiple modules are allowed to simultaneously send and receive data without interaction. The communication functions can be executed in the power line under the voltage (110/220V) and the frequency (50-60Hz). The protocols among modules can be set independently without any special protocol definition for modules. This module can be applied to a wide range of fields, including system monitoring, and control and data communication with other devices.

3. **Results and Discussion.** The host computer screen is shown in Figure 5. The man-machine interface is accomplished by LabVIEW. In control, this system takes remote control of three pieces of equipment as an example. The host computer can command controllers ON/OFF in real-time, or command them at a set time. In data collection, this system takes collecting two detection modules data as an example. The measured data of the detection module 1 includes voltage, current, apparent power, and real power. The measured data of the detection module 2 includes three branch currents and a total current. These measured data will be displayed graphically on the screen for easy monitoring. After pressing key "saving", the measured data will be saved in storage.

The actual devices of detection module are shown in Figures 6 and 7. These modules are suitable for the 110V/220V single-phase power system. Measurement parameters are as follows: AC voltage 0 to 220 (V), AC current 0 to 3 (A), phase angle $-\pi$ to $\pi$ (rad),

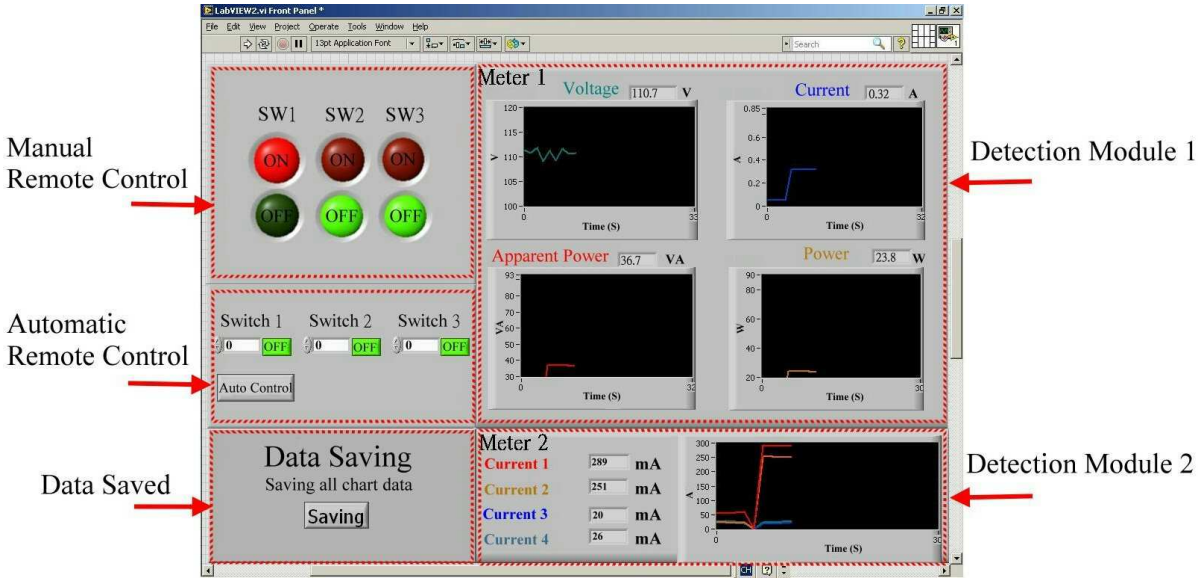


FIGURE 5. Screen of host computer

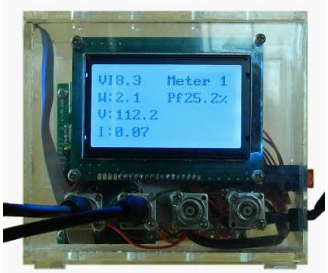


FIGURE 6. Detection module 1

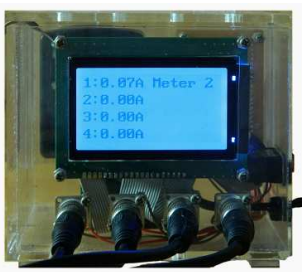


FIGURE 7. Detection module 2

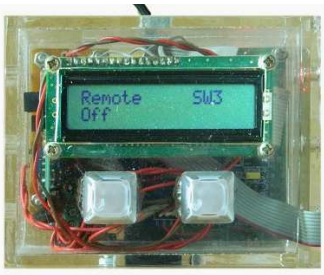


FIGURE 8. Control module

real power 0 to 660 (W), and apparent power 0 to 660 (VA). The LCD display is updated every two seconds. The detection module can connect with the host module through the power line, and transfer all electric information to the host computer for monitoring. In Figure 6, the detection module can measure voltage, current, power, apparent power and watt-hour with embedded power quality chip. In Figure 7, the detection module can measure four current signals.

The actual device of control module is shown in Figure 8. This module has an ON/OFF switch, and is suitable for the single-phase, 110V, 60Hz power system. The control module can switch load by field control, and can also operate load according to the command of the host computer via the power line.

In field test, the transmitted distance between two points for carrier signal can reach to about 200 M. However, when the load on power line is heavy, it can only be transferred about 30 M. In this condition, the line impedance could drop drastically and highly reduce the carrier signal. Currently the wireless transmission is a more common way, but in a home or office environment, the walls seriously affecting the quality of wireless transmission, PLC will undoubtedly become one of the best solutions of data transmission to the smart home.

4. **Conclusions.** The paper establishes the smart grid of the home area network with a host computer, two detection modules and two control modules.

The host computer can command control module to switch electrical equipment, can collect measured data from detection modules, and can analyze these data. The man-machine interface of host computer is accomplished by LabVIEW. Through graphical panel on the computer screen, the operation will be more simple and clear.

Detection modules can measure voltage, current, real power, reactive power, apparent power, and power factor. The detection module can transmit the electrical information to the host computer through the power line for monitoring purposes.

The control module can switch load by field control, and can also operate load according to the command of the host computer via the power line. The operation status is displayed on LCD. The control module can transmit the operation status to the host computer through the power line for monitoring purposes.

In short, this paper has established the smart grid of the home area network by power line carrier, with the expectation of spreading power monitoring to the general public.

The future can be integrated Wi-Fi, Zigbee and other communications technology, which makes smart grid of HAN be more complete and robust.

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