GSM-Controllable Power Switch System for Industrial Power Management

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Abstract - In this paper we describe the GSM Power-Controlled Outlet System (GPCOS) with a scalable mechanism for industrial power management. The GPCOS integrates the multiple AC power points and a simple low-power microcontroller into a power outlet to switch the power of the sockets ON/OFF and to measure the power consumption of plugged electric industry appliances. Our GPCOS consists of four scalable modules, that is, the Essential Control Module, the GSM Module, the Ethernet Module and the Power Measuring Module, which together provide an outdoor remote control and monitor of electric industrial appliances. We use a Short Message Service to achieve control and monitoring through a GSM cellular mobile phone for remote use anytime and anywhere.

Keywords - Industrial Power Management, GSM, Short Message Service, Remote-Controllable Outlet System.

1. Introduction

Industry power consumption tends to grow in proportion to the increase in the number of large-sized electric industries. Industry power management is required to save energy and reduce carbon dioxide emissions [1]. To implement industry power management, networked electric industry appliances with control/monitoring capabilities and industry networks without new wiring are indispensable. Together with the construction of access networks, several standards for wired industry networks have been proposed and developed [2]. The static function is indispensable for a industry network so that the user can install and replace electric industry appliances without need for any special knowledge. The static function discovers electric industry appliances in a network, assign an ID to each appliance, and generates an entry for controlling and monitoring the interface from the industry network [3]. However, electric industry appliances without expansive functions and a conventional power plug which have deteriorated from their interference have made it difficult to build such advanced systems [4].

The Industrial Energy Management System (IEMS) divides the network capability by means of both minimum interface software embedded in electric industrial appliances and separated network adapters. Setting up a system without new wiring is a major concern in a wide variety of applications such as video monitoring, power control and the management of electric industrial appliances [1]. Imagine a private industrial equipped with motion, light, temperature and other sensors and actuators for opening the door, dimming the light, controlling the heating and so on. These sensors/actuators can be used to enhance the individual's lifestyle, e.g. the air

conditioner is turned on automatically when the owner of the house comes industrial and the light is switched on in points where motion is detected. Existing solutions for industrial automation fall short in that most of them do not address security aspects in an appropriate way[5]-[7].

Mobile phones have become one of the most popular communication devices among most of the people around the world, and the Short Message Service (SMS) is popular among mobile phone users as a cheap and convenient method of communicating. Therefore, SMS technology is a common feature with all mobile network service providers. Since the use of SMS technology is a cheap, convenient and flexible way of conveying data, researchers are trying to apply this technology in many different areas that are not covered by service providers at present [10], [11].

This paper is organized as follows. In Section 2 the GPCOS is introduced. In Section 3 the user-friendly control design is described. In Section 4 the implementation results are summarized. In Section 5 our conclusions are presented.

2. GPCOS Design

An AC power outlet is an electrical device consisting of a cord with a plug on one end and several sockets on the other.

The WPCOM connected to an AC power outlet is made up of multiple AC power sockets, an Essential Control Module, a GSM Module, an Ethernet Module, a SD Card Module and a Power Measuring Module. The complete block of the WPCOM is shown in Figure1.
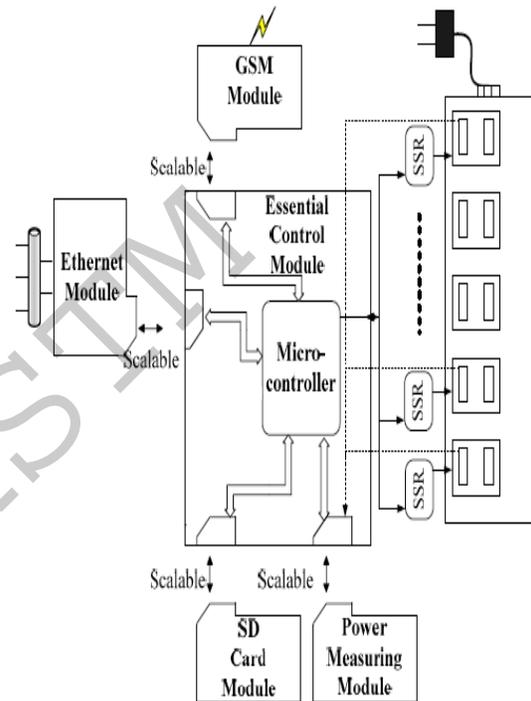

Figure 1The complete block of the GPCOS.

To provide a scalable configuration with different costs and characteristics, we have designed the GPCOS based on the function module mechanism.

We have used the Solid State Relays (SSR) to switch each socket into which an electric home appliance can be plugged. SSR have been utilized to replace mechanical relays because of their many advantages, including miniaturized

configuration, elimination of contact bounce, low-energy consumption, decreased electrical noise, compatibility with digital circuitry and high-speed switching performance. These SSR also provide isolation between a control circuit and a switched circuit.

The microcontroller in the Essential Control Module has four functions: processing commands from and the Ethernet Module and SMS commands from the GSM Module, controlling the SSR ON/OFF, monitoring the status of electric home appliances and transmitting the power status and measured data to the SD (Secure Digital) Card Module. The complete circuit diagram of the Essential Control Module is given in Fig. 2.
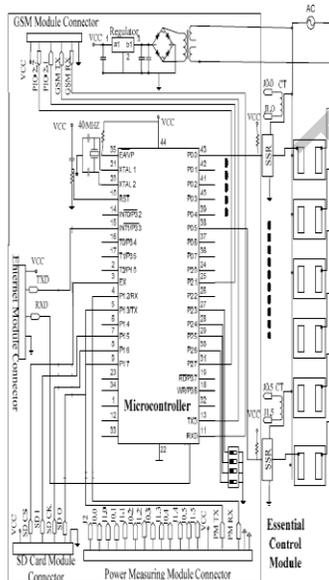

Figure 2 Circuit diagram of the Essential Control Module.

The GSM Module is specifically designed to connect to the Essential Control Module thus allowing calls to be made using the GSM cellular mobile phone network. Because the GSM Module is supplied SIM Card-free by the service provider the user can use the network of his choice. The GSM Module provides a remote GSM mobile to control the system using the SMS. The complete circuit diagram of the GSM Module is given in Fig. 3.
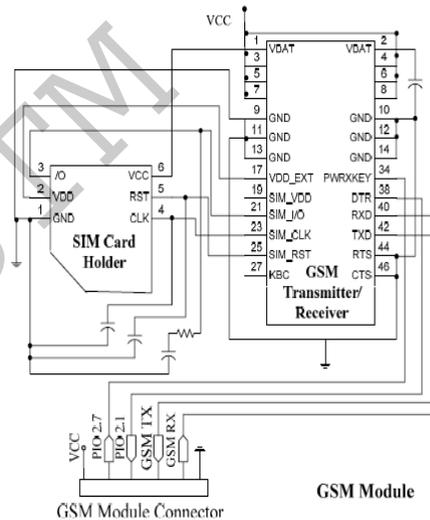

Figure 3 Circuit diagram of the GSM Module.

The Ethernet Module is a true Serial-to-Ethernet converter that connects electric home appliances to the Internet based on UDP protocol, thus allowing the user to control and monitor electric industrial appliances over the Internet. The complete circuit diagram of the Ethernet Module is given in Fig. 4.
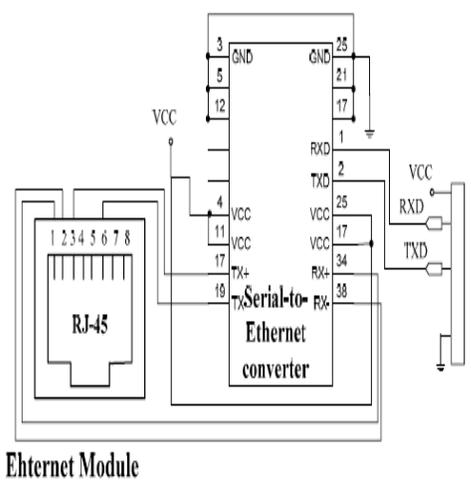
Figure 4 Circuit diagram of the Ethernet Module.

To show the actual status of the electric home appliances, and to control the power ON/OFF we use the Power Measuring Module, which is a measuring circuit containing four parts: six current transformers (CT), an electrical power detector, a multiplexer and a power load microprocessor. The six CT are installed in the AC power outlet, as shown in Fig. 2. The load current of each socket is measured by the CT. By using the Hall Principal Effect the charge carriers in the CT become deflected by the magnetic field and give rise to an electric field which is perpendicular to both the current and the magnetic field, as the load current changes the output voltage signal. The voltage signal is transited to the power measuring module via the connector. The electrical power detector transforms the voltage signal as digitized data for the power load microprocessor. The power load microprocessor receives each socket datum via the multiplexer. The complete circuit diagram of the Power Measuring Module is given in Fig.5.
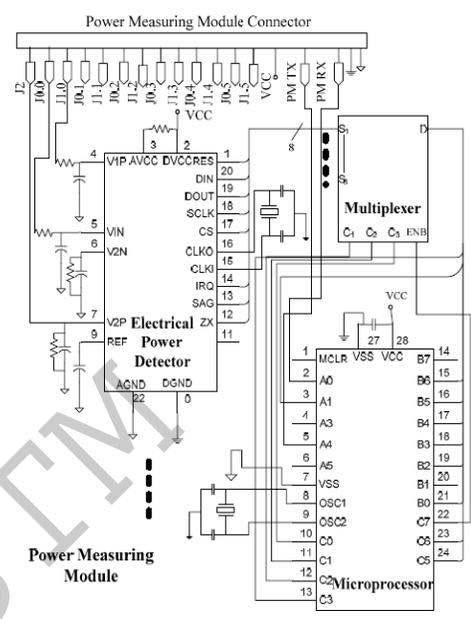

Figure 5 Circuit diagram of the Power Measuring Module.

The SD Card Module is to store the status and measurement data of the electric home appliances. It provides an interrupt type of transfer mode to improve the data transfer performance between the microcontroller and the SD Card. The complete circuit diagram of the SD Card module is given In Fig.6.
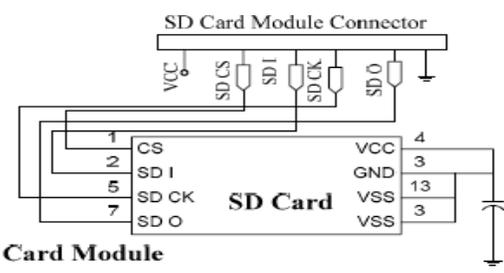

Figure 6 Circuit diagram of the SD Card Module.

Fig. 7 shows the control flow chart of the WPCOM. In the initial mode of the WPCOM the system mechanism checks the hardware configuration to detect which module is installed in the GPCOS. If the Power Measuring Module is installed in the WPCOM, the system measures the power consumption of each socket cyclically. The sources of the control commands can be the PDA, the Internet and the GSM. If there are no control commands, the microcontroller stores the current power status. If the system has received a command, it checks to see whether the command is for the room controlled by the GPCOS or not. If it is, the microcontroller turns the power ON/OFF or sends power data according to the command. If the command is not for any room controlled by the GPCOS, the command is broadcast over the Ethernet network.

Figure 7 the control flow chart of the GPCOS program.

3. Control Design

The GPCOS provides the user with a way to control and monitor the power of electric home appliances by using GSM cellular mobile phone as shown in Fig. 1. When the remote user send the SMS with a control command by a GSM cellular mobile phone to the phone number of the WPCOM, the GPCOS receives it and checks whether the sender is allowed to control the home network. Then the GPCOS confirms the SMS command format. If the message fits in with the command format, the GPCOS changes the power state of electric home appliances or sends an SMS with the power data to the GSM cellular mobile phone. Thus the user can control and monitor the power state by use of the GSM cellular mobile phone anytime, anywhere. With a GSM module installed in a WPCOM it is possible using a GSM cellular mobile phone to:

1) Request the current status (ON/OFF) and power consumption of any point in a GPCOS.

2) Set any the current status of any socket in a GPCOS to a new status.

3) Receive a notification (alert) message that a predefined condition has been met.

Control by PDA:

We have designed this PDA control software using Matlab2009b, which supports the Graphic User Interface (GUI) thus allowing the user to
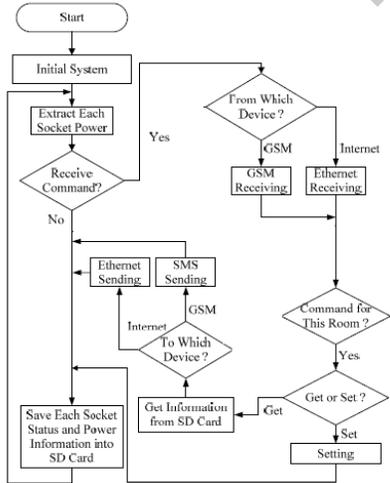
easily control and monitor the electric home appliances' power ON/OFF. The PDA shows the power status of each socket in the display area. The status fields show whether any electric home appliances plugged in the sockets are in use or not. The PDA shows the power consumption and the accumulated energy used by each electric home appliance in the display area. In the control field of Fig. 12 the PDA sets up ON/OFF and sends a command to the WPCOM immediately after pressing the "ON/OFF" button. The PDA waits for an acknowledge command from the GPCOS. The control field sends its command every three seconds if it doesn't receive an acknowledge command, to guarantee that the power control command can be executed without being lost.

Control by Internet:

We have designed this remote control software using a typical Winsock and network protocol component to transmit/receive commands. The remote control software is installed in the PC or the Notebook connected to the Internet. It can control electrical home appliances when the user is out door. The structure of the network connection of the remote control by Internet is a Host-Client structure. The client installed remote control software sets the IP address and PORT, then sends a request to the WPCOM, creates a link and starts to link both client and

GPCOS. The remote user can access a GPCOS with the Internet connection. By means of the Internet the user can control and monitor the power consumption status of the electric appliances. The remote control software uses a GUI which provides the user with an easy way to control/monitor the power status of electric home appliances.
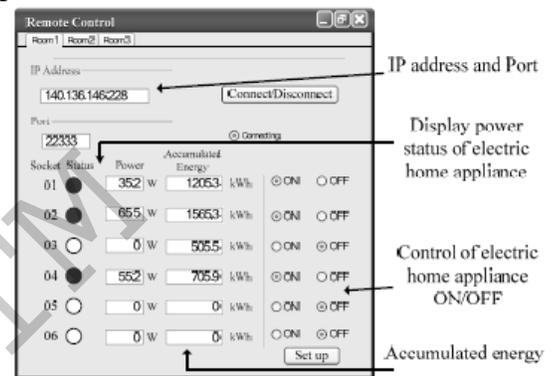

Figure 8 The GUI of the internet control software.

4. IMPLEMENTATION RESULTS

The final implementation of the GPCOS is shown in Fig.14. The entire hardware prototype circuit of the GPCOS is now implemented on a test board(excluding the SSR and sockets).

Figure 9 hardware prototype of the GPCOS.

By using Ethernet the GPCOS enables the local network user to connect a wide range of electric home appliances easily and simply, thus eliminating the need to purchase proprietary or additional cabling to connect individual devices. The user needs only to follow three steps to finish installing the remote- controllable power outlet system indoors.The GPCOS also consumes power. The average current of a GSM Module is 65 mA with maximal 82 mA while communicating, that of the Ethernet Module is 33 mA and 45 mA. The average current of an Ethernet Module is 25 mA, that of the SD Card Module, the Power Measuring Module and the Essential Control Module is 21 mA, 23 mA and 47 mA respectively. The average power consumption of the GPCOS can be calculated as shown in Table V. The total power consumption of a WPCOM is about 1.04 W and increases when the number of sockets of the GPCOS increases.

An additional advantage of the Power Measuring Module is that it also detects the use status of an electric appliance's power, in addition to controlling the points ON/OFF state. In this experiment the Power Measuring Module detects an electric home appliance's power consumption ranging from 1W to 1200 W. We can extend the range to detect lower and higher power consumption from 0.47 W to 2500 W by changing the CT which can increase its volume by half.

5. Conclusion

In this paper a remote-controllable power outlet system and the key components for industrial power management have been developed. To realize remote control, the Bluetooth, the GSM and the Internet technologies for power management have been integrated. The proposed WPCOM is designed for wireless monitoring and controlling of different electric home appliances connected over a Bluetooth network in a home environment. The WPCOM also allows a GSM cellular mobile phone using SMS and PC or Notebook using the Internet to monitor and control electric appliances at remote locations.

The field experiments reported in this paper has demonstrated that this new system can be

practically implemented and provides adequate results. While this study has its limitations, it is hoped that it will serve as a basis for further study of home power management strategies for various electric appliances.

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