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INTELLIGENT ENERGY SAVING SYSTEM BASED ON STAND BY POWER REDUCTION FOR HOME ENVIRONMENT

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ABSTRACT

Energy saving has attracted great attention as a global issue because of recent environmental problems. As a part of energy saving efforts, governments are operating policies that encourage the distribution of energy saving systems. Also, individual households are voluntarily installing energy saving systems to reduce electric power consumption. However, due to fixed system architecture, the existing systems have a disadvantage, lacking in scalability and usability. In addition, the existing systems bring up immense inconvenience as it returns to standby mode after automatic standby power cut-off. Therefore, we propose an intelligent energy saving system to solve these problems. The proposed system controls the power based on the hierarchical relationship among home appliances, along with the relationship between user activity and home appliances for standby power reduction. We designed and implemented the proposed system, deployed it in the test bed, and measured the total power consumption to verify the system performance. The proposed system reduces total power consumption up to 10.5% .

1.INTRODUCTION

Recently, home is evolving into the zero-energy home [1]. The zero-energy home is the home with zero net energy consumption. In other words, the zero-energy home is the home which is able to supply energy itself ,through the distributed energy generation and the reduction of energy consumption. Each country has been pursuing various policies, in order to save energy at home. The United States Department of Energy (DOE) announced a plan to supply the zero-energy home in 2020, and to supply the zero-energy building in 2025. The EU, announcing the Energy Performance of Building Directive (EPBD), has set the goal of making all new buildings perform with zero energy by 2020. Canada set a goal of having all new houses accord with a net zero energy standard by 2030, and China is operating a differential tax preference policy, Green Building Label plan and Building and Construction Authority (BCA) Green Mark plan. Major home appliance manufacturers have made a competitive effort to increase the energy efficiency of their products, in order to realize the zero-energy home. In addition, the number of homes recently that utilize the energy generated by a distributed energy resource (DER) system (e.g. a small size photovoltaic system or wind power system) is increasing [2]. However, there are limitations of appliances to increase the energy efficiency, and though the price of a DER system has fallen, it is still too expensive to install in every household, like a TV. Therefore, the installation and operation of an energy saving together with such effort is essentially necessary, because it may significantly save the energy that is unnecessarily wasted, at low cost. An energy saving system refers to a system that saves the energy consumed in a building or home, by cutting off the wasted electric power such as standby power [3]. Recently the energy saving

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system that has a function to automatically cut-off the standby power has been launched on the market. The smart electricity meter, which is presently distributed in many houses is similar to the energy saving system, but this own differences in functional aspects from the energy saving system. That is, the smart electricity meter mainly implements the function of monitoring the electric power, but the energy saving system is a system that includes not only a function to monitor the power, but also a function to control and network. With such necessities, the energy saving systems (e.g. the energy saving outlet) have been installed to operate. However, existing energy saving systems have several problems. The biggest problem of existing systems is their low extensibility and usability, because they are operated in a fixed form (both for hardware and software). For example, in terms of hardware, existing systems have the fixed roles of each socket, and there is no inter connection between these systems. Furthermore, they operate as a stand-alone system, according to predefined functions, or operate as a centralized system. Such a fixed structure makes it difficult for the system to be functionally updated, which lowers the extensibility and usability of the system. In terms of software, most of the existing systems operate based on predefined rules. Thus, it is difficult to satisfy a user's variable needs, and it is difficult to expect lots of energy saving effect, because the user's activity pattern.

Dynamic control according to the behaviour of residents: The important issue in existing energy saving systems is when and which appliance should have its standby power cut off, and when they should be recovered to standby mode. In particular, the issue of deciding the time to recover to Standby mode is very important for an energy saving system. Since the home appliance does not operate when the standby power is cut off, a significant inconvenience is caused, because the resident has to check continuously whether the standby power for a specific device is cut off, or not. Therefore, this paper proposes method to cut off the standby power, and to recover to standby mode, based on the behaviour of residents.

2.PROPOSED METHOD

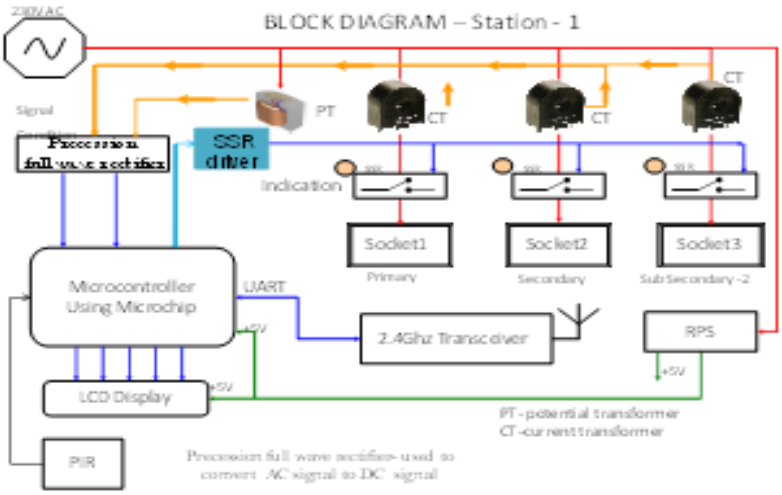

Fig.1.Block Diagram of Station 1

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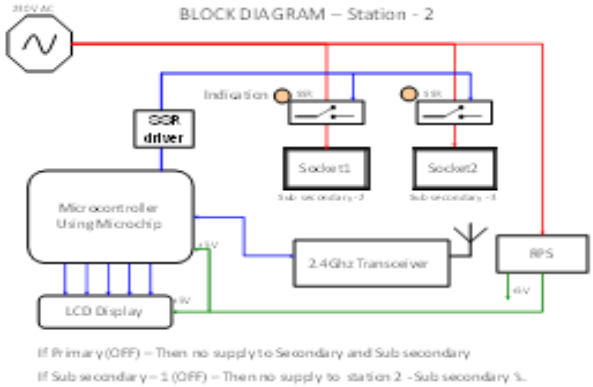
Many studies on energy saving systems have been conducted, long with great concern about energy problems. These studies mainly focus on shutting off standby power, and reducing wasted energy. Song et al[4]proposed a wireless-passive infrared (PIR) sensor detects the presence of a human body, and sends information to a base station, to switch on/off the home appliances. Abe et al [5] proposed a smart tap type home energy management system (HEMS), which uses a smart tap to measure the power consumption,



Displays the power consumption of each electric appliance, and delivers the measurement data to the server in real time, without any external sensor. Mrazovac et al [6] presented a smart outlet, which is controlled and monitored by users, and this executes a predefined operation, depending on power consumption changes. Kau et al [7] introduced a power management technology that performs remote control, using cloud networks. However, these studies described above presented energy saving systems that monitor the power consumption, and manually switch on/off the appliances. That is, the energy consumption can be reduced only through user intervention. On the other hand, Tasi et al [8] focused on automatic power control considering the standby power of the appliances plugged into the outlet. A PIR sensor enables power for the appliances, whenever it detects an approaching user. Otherwise, it disables the power, after the ongoing work is finished. Han et al [9] proposed a power outlet considering waiting time, which means the time before cutting off the electric power. In order to eliminate the waiting time, both power outlet and appliances plugged in the sockets are turned off simultaneously, using an IR remote control through a ZigBee hub. Furthermore, the information of the appliances is kept seamlessly, even though the appliance is moved to a different outlet.

3. INTELLIGENT ENERGY SAVING SYSTEM

The IESS consists of an energy saving device (ESD), energy saving agent (ESA), and energy saving server (ESS). The ESD is an element that implements the key roles in the proposed system, and a device that actually cuts off the power. A light-weight (8-bit) microcontroller unit (MCU) is mounted in each ESD, so that rule-based control is possible. In particular, since the ESD has flexible middleware architecture, an adaptive operation based on stand-alone or cooperation-based type is available, according to various situations. The ESD cuts off the standby power based on a threshold value, and implements the function to return to standby mode based on the user's behaviour.

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STAND ALONE TYPE

The stand-alone type performs the cooperation-base power control by using a hierarchical relationship between the home appliances without the ESA and the ESS. If the size of the space is small enough to be able to communicate via a ZigBee technology or if the number of appliances installed is small, it is inefficient to install the high-cost server. In this case, it is cost effective for the IESS to operate as the stand-alone type that only uses ESDs.

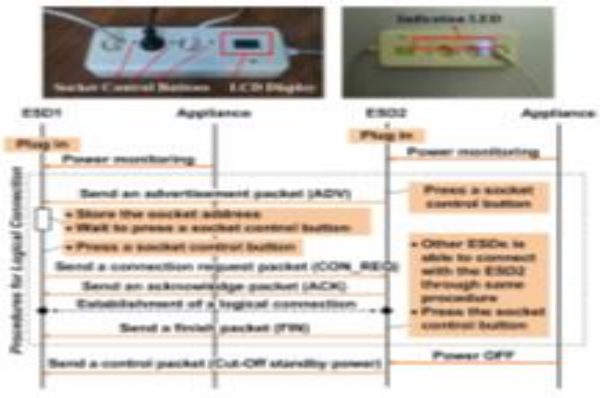

Fig.3. Procedures of a logical connection between the main-socket and sub sockets for cooperation-based power control

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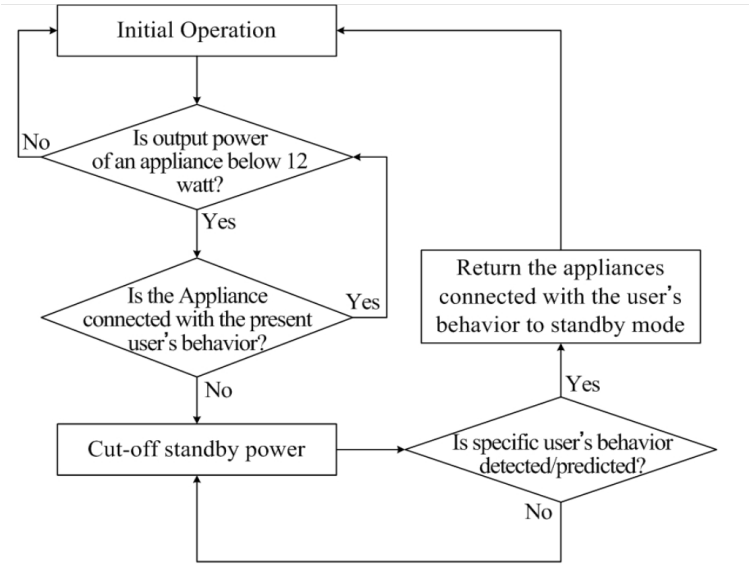

Fig.4. Flow Chart

standby power, is to determine when to return to standby mode, from the standby off mode. Because it is not possible to control the home appliances, when the standby power is cutoff, the user has to check if the stand-by power is cut off or not each time to use an appliance. This causes the greatest inconvenience to the user. The existing solution uses a remote controller for returning to standby mode from standby off mode. However, this method also causes inconvenience, because the user has to repeat the two times control, whenever he or she uses the home appliance. A timer may be used as an alternative solution. This is a method to return to standby mode automatically when a certain time passes, after setting the time. However, this method causes the same inconvenience, when the home appliance is operated before the predefined period. Another method is to turn on the home appliance using the IR transmitting part of the energy saving systems, after returning from standby off mode to standby mode first, when pressing the power-on button of a remote controller of the home appliance. However, in this case, only the home appliances that are operated by remote controller could be used. Therefore, this paper proposes a method to return to standby mode based on the user's behavior.Thus, this paper proposes the technology to return the appliance to standby mode based on the user's behavior.

Home appliances are used at the same time, according to the user's behavior. Users transmit their next behavior to the ESA through their smart phones. Then, ESA returns all the home appliances in connection with the users'next behavior to standby mode. When users finish the behavior, they also transmit the information to the ESA through smart phones. Then, ESA cuts all the standby power for the home appliances in connection with the finished behavior. This method is simple but has a considerable effect. First, as the related home appliances are controlled according to the behavior of the users, it is much more convenient than to control each home appliance separately. And secondly, malfunctions due to prediction error can be prevented since the next behavior of the users conforms accurately.

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4.IMPLEMENTATION

A 2.4GHz ZigBee transceiver module is used for communication. The ZigBee technology has been widely used for home automation because of its low-powerand low-cost characteristics. The switched-mode power supply (SMPS) plays a role of supplying power to the MCU or the peripheral components by converting AC power source to DC power source. The power metering IC is used for measurement of the power consumption of each socket based on gathered data through the current transformer (CT) sensor. The MCU can control a solid state relay to cut off standby power and return to standby mode. A variety of information such as energy consumption is displayed via a LCD.

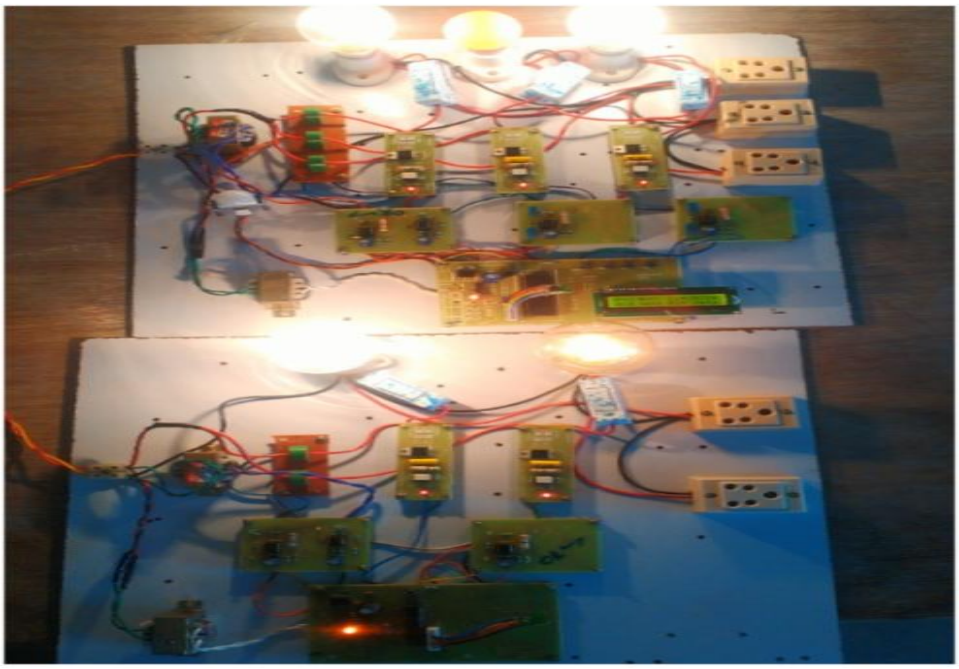

Fig.5. Hardware Implementation

In order to verify the energy efficiency of the proposed system, we installed the proposed system at a real home test bed, where a family of four (father, mother, son, and daughter) reside. We measured energy consumption of the test bed for a week before the system installation and a week after the system installation. In the case of the test bed in which the measurement was carried out, the father was an engineer who works Monday through Friday, and normally starts at 8:00 a.m. and ends at 6:00 p.m. The mother is a house maker, son and daughter are high school students who usually leave for school at 8:00 a.m. like their father, and come back at 4:00 p.m. In order to ensure equality, during the period of measurement, activities during the weekends for both of the two weeks were equally restricted. The energy saving rate for each day of the week varies slightly, depending on the living pattern of the residents. The proposed system reduced energy consumption up to approximately 10.5% on average.

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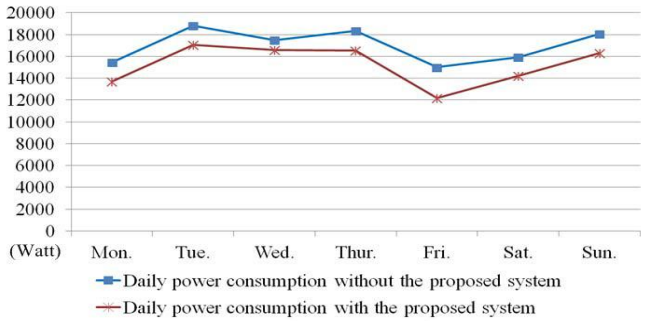

Fig.6. Comparison of daily power consumption

CONCLUSION

In this paper, we proposed IESS that automatically blocks standby power. Cooperation-based power control algorithm was proposed. The proposed algorithm can significantly save standby power using the hierarchical relationship between home appliances. Additionally, we also proposed a method that simultaneously minimizes users' inconveniences and standby power, based on the users' behaviors. By proposing the distributed energy saving scheme based on adaptive middle ware we reduced costs by decreasing the load of the central server, and improved system efficiency by reducing response time. We designed and implemented the proposed system, deployed it in the test bed, and measured the total power consumption to verify the performance. The proposed system reduces total power consumption up to 10.5%. We expect this study to contribute to providing guidance on the development of an automatic standby power cut off system. As a further work, we are planning to develop a high accuracy algorithm that automatically recognizes users' behaviors through minimum input from users.

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