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Intelligent domestic electricity management system based on analog-distributed hierarchy

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A R T I C L E I N F O

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A B S T R A C T

Electricity management system has been extensively investigated for efficiently monitoring and controlling domestic power. Nevertheless, the existing designs are generally rough, inflexible and complex, which leads to poor convenience in practice use and performance evaluation. In this paper, a systematic structure of intelligent electricity management system is firstly constructed and then corresponding multi-task scheduling algorithm based on embedded system is proposed for facilitating domestic power management. The proposed architecture accomplishes the system functions on two interactive modules. And this architecture is very beneficial to effective operation and intelligent management. Furthermore, real-time performance of the presented scheduling scheme is researched by a constraints model and the corresponding simulation result shows a good performance, where the overtime ratio is 10.3% under an extremely bad condition. Besides, the relationship between overtime ratio and sporadic tasks is derived in a general way and also verified by simulation.

1. Introduction

The double pressure from energy crisis and combustion emissions drives human being to pay more attention to domestic electricity management which is one of the most significant parts of smart grid [1,2] and smart home [3–5]. With the aid of the integration of advanced technologies [6–9], there is no doubt that the intelligent domestic electricity management system contributes to the environmentally sustainable residential system.

Several efforts have been focused on research of the framework for domestic electrical system. In [10], a power management system for home network devices is presented, where power control clients are embedded in each networked device for reducing the electricity consumption. The decentralized layout results in the difficulty of fixing and evaluating the whole system. Zigbee is used in the achievement of [11], where the wireless power outlet is just a switch controlled remotely without other functions. Choi et al. [12,13] design an intelligent energy management apparatus based on MCU (Micro Control Unit). The equipment can control power simply by switching on/off and record the data of electricity. However, it is difficult to enhance the controlling capacity and add more functions, since the structure of the apparatus can hardly be extensible. In [14], the concept of cyber-physical is fused in home device power management. Utilizers manage electricity loads by means of a multi-agent system involving evaluation, monitoring, controlling and energy resource agents. This design may be considerably effective, yet it is just a general basic prototype. Moreover, a theoretic study is illustrated in [15], where a smart home energy system is composed of many dispersive parts including smart meter, smart socket/switch, grid friendly appliance controller, smart interactive terminal, and other smart devices.

To keep the balance between centralization and decentralization, in this paper, an intelligent electricity manage system based on analog-distributing hierarchy is developed, which is able to accomplish the functions of electricity access, distribution, monitoring, controlling, and overload protection. The implement architecture of the system is shown in Fig. 1. Moreover, the scheduling scheme of operating functions is presented, of which the real-time performance is researched and evaluated by a built constraint model.

The remainder of this paper is organized as follows. A detailed design of the proposed smart electricity management system (SEMS) is presented in Section 2. Correspondingly, the multi-task scheduling scheme and the real-time evaluation model are developed in Section 3. In Section 4, a real-time simulation is done and the real-time index formulas are derived.

2. Structural design of SEMS

The structure of SEMS, which is shown in Fig. 2, is composed of main control (MC) module and solid-state power controller (SSPC) module. It is a kind of analog-distributed construction, i.e., the functions of SEMS are separately arranged on the two modules

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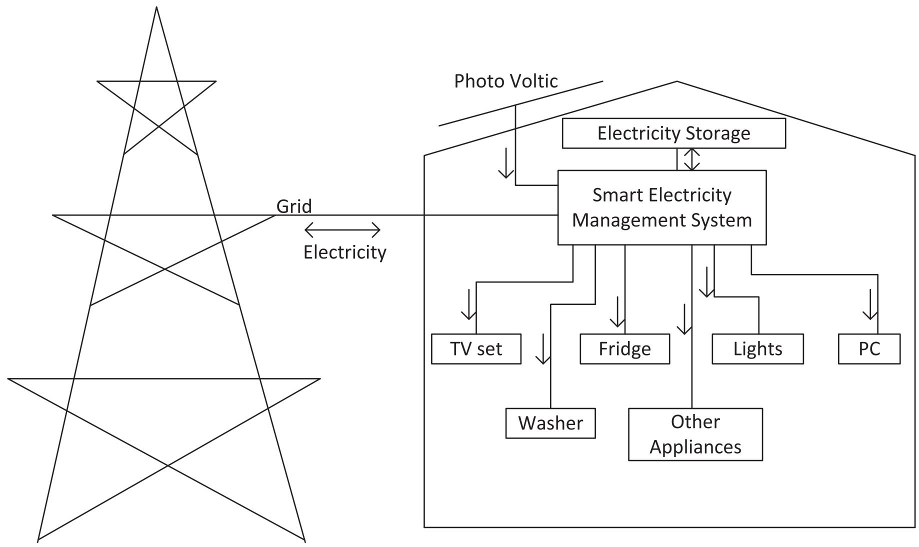

Fig. 1. Smart domestic electricity management system.

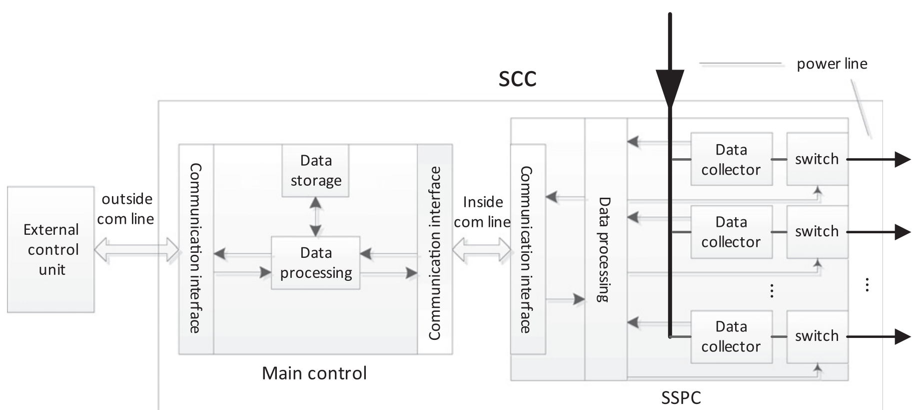

Fig. 2. Structure of SEMS.

with data processing capacity, which are connected by the inside com line. The separated design could permit the controlling capacity to be enhanced by increasing the number of SSPC.

Through the outside com line, users could control the SEMS remotely by an external control unit (ECU). The commands transmitted on the outside com line are related to three categories: turn on, turn off and uploading. According to the different command from ECU, MC will take a distinct action: if the received command is turn on or turn off, MC will send the corresponding command to SSPC; if it is the command of uploading, MC will send the information saved in data storage to ECU. The details of MC will be presented in Section 3 of this paper.

SSPC [16] controls the switch depending on the commands from MC and the state of electricity, and the corresponding illustration of SSPC working status is depicted in Table 1. The parts of data collection make SSPC obtain the data of each power line including the value of electricity and the state of turn on/off at any time. The collected data will be uploaded to MC through inside com line, if the command of uploading is received from MC. The work flow diagram of SSPC is given in Fig. 3.

In SSPC, the semiconductor devices, e.g., MOSFET or IGBT, can be used as power switches. The approach of data collection can choose RMS converter, Hall sensors, or the combination of sample resistances and AD, which could facilitate the way of data acquisition [17,18]. The inside communication can be achieved by RS-422, RS-485, or CAN, which are all serial bus technologies. The outside communication can be reached by Ethernet, power line communication [19], or even wireless communication.

Table 1
The working status of SSPC.

Command	Electricity status	Switch status
Turn off	–	Power off
Turn on	Overloaded	Power off
Turn on	Non-overloaded	Power on

3. The multi-task scheduling algorithm of MC and the constraint model for real-time evaluation

The MC module is designed based on embedded operation system. Its related function tasks are involved as follows:

Task1 (BIT): Built-In Test;
Task2 (ReadFor_Command): receiving the command from the external control unit through the outside communication line;
Task3 (AskFor_Value): transmitting data-uploading command to SSPC and receiving data from SSPC for storage;