Smart Home Electricity Management System Based on WiFi Technology

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Abstract. With the continuous development of the level of economy and the continuous improvement of the level of science and technology, the continuous enrichment of household appliances has led to a decrease in the load factor of the grid and a large difference between the peaks and valleys, which affects the safety and stability of the power grid. This paper introduces the concepts of WiFi technology, smart home and demand response, as well as its development status and trends. Then, this paper designs a smart home power management system based on the theory of WiFi technology and demand response. In this paper, the overall structure of the system, the hardware design and the software design are explained. Through this system, users can achieve an energy-efficient and efficient living environment and better participate in the demand response.

1. Introduction
Due to the increasing progress of society and the improvement of economic level, people's demand for electricity is also increasing. At the same time, it also brings about environmental pollution caused by power generation and waste of electricity. Therefore, how to effectively control electricity consumption has become an important research topic. Smart power consumption is an important part of smart grid, which plays an important role in solving environmental pollution and resource shortage [1].

With the rapid development of science and technology, the world has entered the information age. Due to the continuous advancement of technology, people's requirements for household conditions have become more comfort, convenience and safety, thus giving birth to intelligent buildings and houses. Smart home connects and monitors information-related home devices into the network through the bus of the home network to implement monitoring and control for centralized or remote management. The current development trend of smart home is to control the development of a centralized to distributed control. There are currently four major wireless technologies that is Bluetooth, WiFi, Z-Wave, Zig-bee home in applied intelligence. Among them, WiFi and Zig-bee are the most competitive [2].

The smart home electricity management system relies on demand response technology and advanced measurement system technology to dispatch automatic control systems for household appliances according to suitable power optimization strategies. Therefore, this article will combine the background knowledge of smart grid, use the related knowledge of demand response and smart home to design smart home electricity management system based on WiFi technology.
2. **WiFi technology**

WiFi, the full name is Wireless Fidelity, which is an 802.11b wireless network specification, is a short-range wireless transmission technology with fast transmission speed and long effective distance. WiFi usually uses 2.4G UHF or 5G SHF ISM RF band, which can be automatically adjusted with the signal when it is disturbed, and it is more reliable when ensuring network stability.

WiFi has two modes, Infrastructure mode and ad hoc mode. The infrastructure mode belongs to the traditional AP mode. In the wireless network, there is only one central point. Other nodes access the central point and exchange data through the central point. The ad hoc mode is an ad hoc network mode, and any node can communicate with other nodes without going through the center point.

3. **Smart Home**

The concept of smart home originated in the United States in the early 1980s, calling it Smart Home. It has undergone four generations of development: the first generation completes home networking through coaxial lines and two cores to achieve lighting, curtains and a small amount of security control; The second generation is through bus and IP technology networking, to be able to complete the video intercom and security business; The third generation is a centralized intelligent control system, by the central control computer to complete security, measurement and other functions; The fourth generation that is based on the Internet of things technology can be based on user needs to achieve personalized features[3].

4. **Demand Response**

Demand response (DR) is called power demand response. When the market price of power wholesale rises or system security is affected, the power company will release the signal that the electricity price rises or reduces the direct load compensation to the user, thus guiding the user to change the original habits of electricity utilization, reduce or transfer the power load, to achieve the purpose of peak load shaving, thus maintaining the stability of the grid system [4]. The smart grid demand response project is shown in Figure 1.

At present, China's power demand response still lags behind foreign developed countries in terms of market environment and users. There are problems such as high infrastructure construction cost, inadequate subsidy mode, need to improve the demand response standard system, and need to improve the automation degree [5]. In recent years, China has issued a number of policies related to demand response, which supports its rapid development. In the future, the development of demand response not only needs to combine the demand response support technology to make progress, but also continuously improves the user penetration rate and learns advanced foreign experience, and gradually develop China's demand response projects.

5. **The overall design of the system**

In the whole system of smart home, the smart home electricity management system is the core module, which can be used as an effective management tool for intelligent demand response, and can also be used as a tool to coordinate with the grid company for demand side management, by shifting the electrical load to achieve the purpose of peak load shaving. The smart home electricity management system controls all aspects of home electrical equipment through WiFi technology. It monitors, controls, and tracks the home living environment in real time, which helps to improve the overall benefits of society and achieve new energy-saving. A new home power mode that is energy efficient, safe, and efficient has been realized.

The Andriod system is used as the platform. The system consists of a central processing unit, a WiFi module, a control terminal with a smart phone as a carrier, an intelligent control system, a wireless router, and smart power terminals. The intelligent control system can realize real-time electricity price inquiry, power data query, parameter setting, remote control, power management and other functions. Finally, the Andriod system smartphone can be used to control the household appliances through the WiFi network. A wireless router is a medium for transmitting information.
between a power management platform, a smart power terminal, and WiFi. The smart socket is an execution unit of the power terminal, and is responsible for controlling the on and off of the household electrical equipment [6]. The overall structure of the system is shown in Figure 2.

This article selects STM32 core controller as the central processor, Qualcomm's QCA9531 chip as the WiFi module, and Android platform based on the Android system as the control terminal.

### Figure 1. Demand response project classification

### Figure 2. The overall design of the smart home electricity management system

#### 6. The hardware design of system

The main role of the central processor is to perform information transmission with the host computer, receive real-time operation instruction from the control terminal, parse and execute corresponding work. The system uses STM32F107 processor and QCA9531 model WiFi wireless communication module. STM32F107 processor mainly realizes data communication with WiFi wireless communication module through serial port, and provides 5V power for WiFi wireless module. In this system, the core controller's function is to collect, process, and forward data from the wireless communication module and the intelligent terminal module. The QCA9531WiFi wireless communication module embeds OpenWrt firmware, and implements the data forwarding and transmission of the QCA9531WiFi wireless communication module by configuring the network serial port function and push function of the OpenWrt system.

##### 6.1 STM32 processor module

The STM32F107 microcontroller uses the Cortex-M3 core with CPU speeds up to 72 MHz, making it suitable for applications requiring connectivity and real-time performance. The MCUs feature 64-256KB of on-chip flash memory, 64KB of SRAM and 14 communication interfaces, and a USB OTG full-speed (12Mb/s) device, host and OTG mode control module. The power module used in the STM32F107VCT has an input of 5V DC and an output of 3.3V DC. The USB Device interface on the development board is a mini-USB port, and the electric shock is small, and no power is taken from the PC. The biggest highlight of the STM32F107VCT chip is the integration of most of the mainstream peripheral networks, CAN, USB, UART, motor control and so on.

The STM32F107VCT series has the advantages of interconnected interfaces and many internal resources, the F107 increases the number of the IEEE Ethernet interface, it has two IIS audio interface, and all 64kb SRAM cache.

##### 6.2 WiFi wireless communication module

The WiFi wireless communication module in this system uses the QCA9531 chip of Qualcomm. Compared with AR9431 chip, QCA9531 chips lower in price than AR9431 chips, except that its frequency will be higher, up to 650MHZ, and the memory can reach up to 128MB. It has the advantages of boosting the CPU, reducing power consumption, and lowering the heat of the chip.
Although both chips support USB interface, QCA9531 adds an external interface, supports MINIPCIE interface, can be extended to 5G dual-band and LTE data module applications.

7. The software design of System

The software design of the system is based on the Android operating system. This article uses the Android operating system as a platform for the development of smart home electricity management system. By installing an APP on a smart phone, users can monitor and better participate in demand response management, realize remote management, reduce security risks, and save power consumption. It is practical to apply modern advanced technology to people's lives.

This article chooses MATLAB GUI user interface to simulate the design of the interface. APP software interface is mainly consisted by welcome interface, login interface, the main interface. The main interface is divided into real-time electricity price inquiry, power data query, parameter setting, remote control, power strategy management and setting and other sub-modules. The main interface is shown in Figure 3, and the client interface operation design is shown in Figure 4.

![Figure 3. Main interface of Smart home electricity management system](image1)

![Figure 4. Design of client interface operation](image2)

After logging in to the account, users can enter the main interface. On the real-time electricity price inquiry interface, users can check the real-time electricity price information within 24 hours. The smart home electricity management system can adjust the use of household electrical equipment according to the real-time electricity price information to meet the requirements of peak cutting and valley filling, and improve the effectiveness and reliability of power supply.

In the electricity data query interface, users can query the usage of different power equipment in the selected date in the 24-hour period and the total electricity cost, so that users can participate in the demand response, so that users can manage the usage of power equipment better.

In the parameter setting interface, users can select the load (such as rice cooker, water heater, washing machine, etc.), and set the voltage, current, power factor and priority of the power device. The system sets the parameters of the household electricity optimization strategy that meets the user's expectations by setting parameters, and reduces the electricity expenses as much as possible while satisfying the user's needs.

In the power policy management interface, users can optimize the power consumption period of each power device obtained by the optimized algorithm program according to the parameter value set by users, and take users' demand into consideration, thereby reducing the electricity cost and achieving the purpose of energy saving.

Take the remote control interface as an example, and its interface is shown in Figure 5. In the remote control interface, firstly, the users need to add the electrical equipment that needs to be
remotely controlled to the system, and secondly, users can choose to connect or disconnect the specified electrical equipment according to users’ needs, or select the appropriate mode (normal mode or energy saving mode) to adjust the switch for electrical equipment. Through the remote control, the system not only can optimize the load management, but also bring convenience to the users’ life and save the start-up time of the load.

The subroutine flow chart of remote control interface is shown in Figure 6. In the remote control interface, there are two control buttons: “Connect” and “Exit Connection”. After clicking the connection button, it will start to connect the device. After the successful connection, users can choose to turn on and off household appliances. After clicking the exit button, users can choose whether to disconnect or not. If yes, users can disconnect the equipment and exit the current interface to return to the main interface; If not, then can disconnect the equipment and return to the main interface to control other submodules, then stay in the current interface.

8. Conclusion
First of all, this paper introduces the concepts of WiFi technology, smart home and demand response and its development status and trend. Secondly, this paper aims to save users’ electricity tariffs, and to transfer power load. This paper designs the overall scheme of the smart home electricity management system. The STM32F107VCT series and QCA9531 chips are used to control the smart home electricity management system through the Android platform. Finally, the software design of the APP is performed using the GUI user interface of Matlab.

References
[1] Tompros, Spyridon, et al. "Enabling applicability of energy saving applications on the appliances of the home environment." Network IEEE 23.6(2009):8-16.
[2] Liu, Fagui, and H. Zhao. "The Design of WIFI-Based Smart Home Communication Hardware Adapter." Fifth International Conference on Instrumentation & Measurement IEEE, 2016.
[3] Alam, M. R., M. B. I. Reaz, and M. A. M. Ali. "A Review of Smart Homes—Past, Present, and Future." Systems Man & Cybernetics Part C Applications & Reviews IEEE Transactions on 42.6(2012):1190 - 1203.
[4] Han, Sekyung, S. Han, and K. Sezaki. "Development of an Optimal Vehicle-to-Grid Aggregator for Frequency Regulation." IEEE Transactions on Smart Grid 1.1(2010):65-72.
[5] Mercedes Vallés, et al. "Regulatory and market barriers to the realization of demand response in electricity distribution networks: A European perspective." Electric Power Systems
Research 140(2016):689-698.

[6] Bertsch, L. A. . "Development tools for home automation." IEEE Transactions on Consumer Electronics 36.4(1990):854-858.