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Overview of Energy Visualization Technologies for Smart Home

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Abstract

The energy visualization technology of smart homes not only brings convenience to users, but also strives to minimize energy consumption and maximize household electricity efficiency. In this paper, we first discuss the different energy visualization technologies, applications and methods under this topic, and analyze the key points of their advantages. Secondly, the paper proposes a simple smart home energy management system. Being convenient for users and energy managers, the system guides users to change their electricity consumption habits through self-motivation and comparison with other, saves energy consciously and improves energy efficiency.

Keywords: smart home, energy loss, energy visualization

1. INTRODUCTION

In recent years, energy consumption has been increasing, energy conservation and emission reduction have become imminent. Household appliances have become the second largest source of energy consumption for residents. In the United States, the energy consumption of household appliances even accounts for one-third of the total energy consumption. Various countries are developing new energy sources vigorously, in the same time, improving the efficiency of household electricity consumption has a great impact on the utilization of electric energy. Combining energy visualization technology with existing home intelligence makes home energy management more convenient and faster. For this field, various countries have conducted some related research, including Microsoft, Google, and research scholars from various countries. With a visual solution, users can improve their electricity consumption habits through some hints directly and understand whether there is energy waste in smart homes, thereby reduce power consumption.

2. RELATED WORK

Intelligent household is a platform with the residence, which is based on the Internet of Things technology, network communication technology, automatic control technology and so on. From its initial budding period to the current explosive period, the technology has become more and more mature. Users can directly operate household appliances through smart devices such as display screens, mobile phones, computers, and check electricity consumption and electricity costs. In the 1980s, United Technologies Corporation opened the door to smart homes. It started from air conditioners, refrigerators and other equipment, used embedded communication technology to combine with user communication terminals, therefore homes became intelligent. At the same time, energy consumption is also the focus of researchers, electricity consumption has been increasing in recent years. Figure 1 shows the national power generation structure in the past five years. It can be seen that the fuel consumption for power generation is increasing year by year. Figure 2 shows the consumption estimates of different energy consumption terminals in the US Residential Energy Consumption Survey (RECS). Both show huge energy consumption. Therefore, the energy visualization technology of smart home helps users directly reduce energy consumption through a visual display screen.

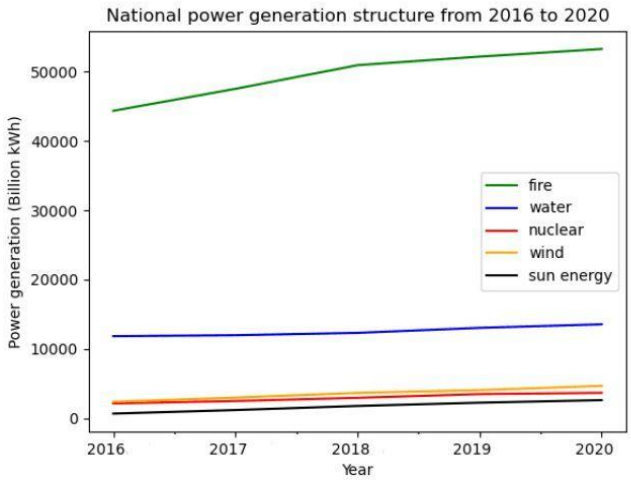

Fig. 1.National power generation structure from 2016 to 2020

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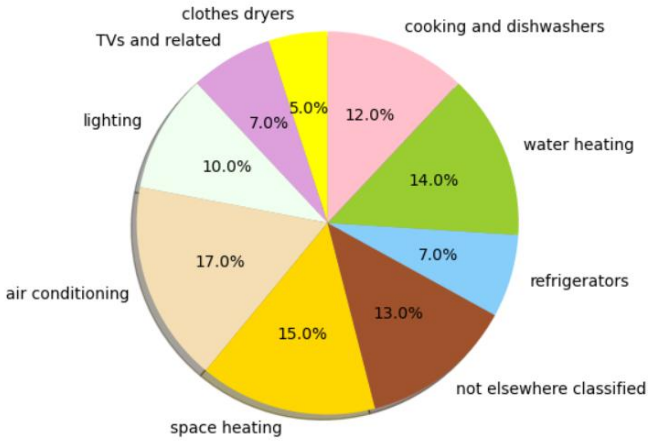

Fig. 2. Residential electricity consumption by end use

AIoT (Artificial Intelligence of Things) aims to send electricity consumption data to users through AI programs. Users can check the electricity usage through mobile phones, computers, and understand the energy usage of the home through some visual interfaces such as graphs and charts [1]. At this time, users can realize their power consumption and compare it from one day, one week, and one month. The combination of artificial intelligence and the Internet of Things is the current mainstream way of energy visualization, the so-called interconnection of things, but technology is not the only factor. If we want to achieve successful and sustainable smart homes, we must fully consider the actual needs of end users[2].Equipment power consumption and operating speed still need to be improved in the future.

Researchers have also made different progress in the energy visualization technology of smart homes. For the existing visualization technology, under the goal of creating high-efficiency energy, 3D visualization technology has made new progress, and it has already been actually constructed and applied by domestic smart power station suppliers. From smart homes to smart cities, the 3D visualization technology of smart energy is applied to the construction of urban models. In order to build a low-carbon life, the energy dashboard based on 3D visualization technology displays both dynamic and static aspects. Cities of different sizes and different regions respectively send energy data streams to city management departments in real time[3].

According to the researcher's research, more energy visualization program design and display effect are shown in Table 1:

Tab.1.Energy Visualization Program Design

Application	Reason for Application
ChArGED [5],[6]	It provides visualization of historical data.
GreenSoul app [7]	It presents both total and device power consumption to the users.
PEAK app [8]	It visualizes energy saving, cost, carbon dioxide emissions, solar power generation graphs, and consumption forecasts compared with other households.
ENTROPY [9]	It shows real-time total consumption data, household baselines, target/goal progression, and daily number of energy peaks.
TED [10]	It shows current power consumption, cost, history, and total location grid demand.

Based on related papers,this paper summarizes a simple smart home energy management systemframework, It takes into account the user's powerconsumption habits, and further solves the problem of power loss, brings a more personalized and intelligent experience to energy management. Data from the National Energy Administration(http://www.nea.gov.cn/),Energy Information Administration (https://www.eia.gov).

3. ENERGY MANAGEMENT SYSTEM FOR SMART HOME

Although smart home energy visualization technology has been developed for many years, the technology is constantly updated and iterated. Based on the basis of numerous studies, this paper removes the dross and selects the essence and summarizes an energy management system. There are mainly three parts in the program: the user data analysis, energy visualization display, energy consumption feedback.

3.1 User data analysis

The popularization of smart meters provides great convenience for consumers and energy managers. Firstly, the program needs to obtain user electricity consumption data and preprocess these data. Then it marks the electricity consumption of users' household appliances and stores the power consumption of different users every day, week, month, and year in the

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database. Finally, this program cleans up the useless information and summarizes it for users to query useful information[4]. Some related algorithm models of machine learning, such as LSTM model, can be used for data prediction, and the prediction results will be sent to customers in the form of charts. Machine learning is widely used in the field of household appliances, [11] uses machine learning algorithms to identify the switch status of household appliances to determine user behaviors.

3.2 Energy visualization display

The concept of energy visualization management is mainly monitored by power monitoring meters, and then by collectors such as Panasonic's DLL, DLU to transmit to the computer for special analysis, and provides energy users and managers with a very intuitive data or graphic to have targeted operations and improvements. Utilizing the aggregation line graph, the classification line graph and the visualization based on the area, summarizes the usage of household appliances[12], optimizes user behavior and reduces energy consumption.

The user's power consumption is displayed on smart devices such as mobile phones, tablets, with visualization technology based on the web program. Energy managers can use big data statistics to investigate and reserve the power records of general household appliances, and classify electrical appliances according to power. On the visualization page, users can see the duration of electricity consumption under a certain power and household power consumption records for one day, one week, and one year. At the same time, users can also browse electricity consumption of other households, so as to remind themselves to save electricity through comparison.

3.3 Energy consumption feedback reminder

After classifying electrical appliances according to power in the background, through interesting prompts, users are reminded on the visualization page to reduce the use time of certain types of electrical appliances. For example, if your electricity consumption is higher than other 95% users this week, the system reminds you that you can reduce the use time of the air conditioner.Consumer incentive technology[13] motivates users to take specific activities in a gamified way. At the same time, when the user's power consumption is reduced, a pop-up window will inform the user of the reduction in power consumption this week, and a certain reward will be given to encourage users to make energy-saving behaviors. After the user checks the energy consumption loss through smart software such as mobile phones, the background database calculates the average electricity time and power consumption of all users to remind the user to reduce the use of a certain type of household appliances through the display. For example, user A has 20 hours of air-conditioning opening time per day, and the average air-conditioning opening time of all users in the community is 16 hours. At this time, the system can remind user A that the air-conditioning opening time can shorten the air-conditioning opening time and have more ventilation.

Finally, smart homes are developing rapidly, and high-tech products have brought users a better sense of experience. In the future, many home energy issues need to be continuously improved. For example, for the temperature and humidity in the air, air conditioners and humidification equipment are able to adjust themselves, call temperature and humidity sensor technology and 3D energy visualization technology to reduce human manipulation and avoid man-made energy waste caused by untimely operation. According to data from the International Energy Agency, the United States' annual electricity consumption is higher than that of China, and the electricity consumed by household appliances accounts for a relatively high proportion of the total energy consumption. Therefore, it is necessary to remind users from all aspects of energy conservation and emission reduction through data visualization.

4.CONCLUSION

Starting from the smart home, this paper describes the related technological innovations of energy visualization, and summarizes an energy management system on the basis of these technologies, including the introduction of machine learning methods, consumer incentive technology and so on. It reminds users to change electricity consumption habits and save energy. However, this is only a framework, and the follow-up needs to continue to deepen the research. For sustainable development, there is still more room for improvement in the energy visualization of smart homes in the future.

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