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Design and implementation of energy management system software in green building

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Abstract. Construction energy consumption has been tied up with traffic and industrial energy consumption at this stage, and has become one of the three major energy users in China. In view of the current problems of prominent energy consumption and the lack of energy management software system in our country, as well as the lack of energy data in the actual operation of green intelligent buildings, the design method of software management system was put forward in this paper, and then the mature software engineering method was used to develop the energy management which can meet the requirement of green building energy saving; finally, in the experiment, it was proved that the energy consumption data analysis module was the main part in the energy management software. Through the statistical analysis and research of the building energy consumption, the energy consumption of the building model was compared and analyzed, so that the equipment efficiency and energy consumption of the building were defined, and the corresponding management and optimization measures were put forward, so as to provide a theoretical reference for the development of green building energy-saving management software.

Key words. Green building, energy management system, management software.

1. Introduction

Because of the huge population base and rapid development of social economy in China, the consumption of resources in China is serious. China has become one of the energy consuming countries in the world. The serious consumption of resources leads to the vicious development of human living environment, which seriously affects people's life and health. Facing such an era background, the government has introduced a series of policies to encourage green development to promote green construction and create a healthy living environment. Green building is a leap in the development of intelligent buildings, and there are obvious differences between the two. The so-called intelligent building is a building that uses high technology to meet the needs of people, while the green building is based on intelligent architecture,

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which covers human life for the pursuit of natural development. That is to say, green building is the integration of intelligent building and environmental consciousness. The formation of green buildings mainly depends on the self-discipline of society to promote green economy, reduce energy consumption, and improve the utilization rate of energy. From the technical point of view, green building is a requirement for technological development and an important achievement of economic reform. The choice of materials for green building is quite severe, which mainly adopts the new energy-saving and environmental protection materials, integrates with the development of the times, and combines with the characteristics of the development of intelligent buildings, so as to effectively monitor and control the system information.

2. State of the art

Green buildings refer to buildings that increase resource utilization but reduce energy consumption, from which, users try their best to reduce resource consumption and save resources, so as to achieve efficient and healthy construction [1]. On the other hand, green building covers a wide range, which is closely related to technology, equipment, materials and environment [2]. In recent years, China's government agencies have introduced a number of green building support policies, and highlighted the importance of green building energy efficiency. Facing such a development situation, we should try our best to realize the new leap of green energy saving construction, so as to promote the steady development of society. Focusing on the development of green building in the world, the annual resource consumption of office buildings is down by about twenty percent with the development of building automation system [3]. According to relevant statistics, few intelligent buildings can achieve energy-saving effect in our country. However, most the energy saving systems in smart buildings are just BAS systems, which can detect the control status of equipment, but the effect is not obvious, and the loss of capital is also raised. Therefore, the development of energy-saving buildings has become a major problem faced by China's construction industry to reduce consumption. In the current technological context, breakthroughs in new technologies are based only on Intelligent buildings, and the energy monitoring system is embedded in intelligent building to realize the optimized management of energy [4]. The development of the leading green building energy management system at home and abroad is based on many of the latest technologies in the Internet community, such as cloud computing, Internet of things and other advanced technologies [5]. Through energy management systems of the Internet of things and cloud computing, the various sensors and controllers within the building group can be fully connected. On the basis of intelligent control and system integration on the construction site, the scattered single buildings are connected into building groups for real-time data statistics, analysis and processing, and the energy consumption of the building group is unified controlled to realize the integration of intelligent building energy control function. And a large number of buildings can form a unified control of energy consumption in a smart city [6].

3. Methodology

In building, the purpose of using energy is to provide comfortable, safe and convenient service for all kinds of personnel in the building, that is, which is people-oriented. Energy efficiency should be analyzed both in terms of real energy consumption data, and the relationship between energy use and human use. Therefore, in addition to the traditional energy transmission efficiency, the concept of energy utilization efficiency should be introduced [7].

The formula for the efficiency of energy transmission is

$$\eta_t = \frac{E}{E_0} \times 100\,\%\,, \tag{1}$$

where E_0 represents the total energy output within the building, and E represents the total energy obtained by the end device.

Energy efficiency is used to indicate the extent to which energy is transferred to the end of the system, that is, the place where people move [8]. The efficiency of energy utilization depends on the distribution and mode of activity of people in buildings (the distribution and activity of personnel are different in different areas of a building, and the frequency of distribution and activity is different at different time periods), which can be expressed by discrete data, and the average efficiency of energy can be obtained by summation method [9]. If the energy is fully utilized, the utilization efficiency is 1, otherwise, it is 0. The area in the building is divided into n units, with hours as time units, and the average energy utilization efficiency can be expressed as

$$\bar{\eta}_t = \frac{\left(\sum_{k=0}^{n} \delta_{kt}\right)}{nt} \times 100\,\%\,, \tag{2}$$

where $\delta_{kt} \in \{0,1\},\ k \in (0,n),\ t \in (0,23)$, δ_{kt} represents the energy efficiency of a given period of time, k represents the zone number and t represents the time period.

For type 2, the meaning of the expression is very clear but cannot be measured accurately, which can only be estimated by the method of estimation, and the energy in the building is always measured at a certain time delay. Therefore, there is no definite method of measuring energy efficiency, which is more based on experience. By recording long-term energy usage, the energy management system can obtain approximate representation of energy efficiency through statistical methods, which is also an original intention of building an energy management system [10].

Another way to achieve energy efficiency is that with the improvement of building intelligence, the passenger flow analysis technology is used to monitor the distribution and activity of personnel in real time, so as to determine the efficiency of energy utilization.

Figure 1 shows the ideal green building with an energy management system.

Building energy management systems, referred to as BEMS, can monitor buildings' energy efficiency and energy use and energy consumption equipment, build building energy information database, and analyze and process it on the basis of database, so as to realize the diagnosis of energy efficiency and control of energy consumption.

The system data classification diagram is shown in Table 1.

Fig. 1. Ideal green building with an energy management system

Table 1. BEMS data classification map

Environmental data	Temperature humidity sensor	
	Illumination sensor	
Energy consumption data	Item metering ammeter	Electricity for air conditioning
		Electricity for lighting outlet
		Power consumption
		Special power consumption

The whole BEMS includes 4 function subsystems, such as detection system, control system, measurement system and analysis system.

Test system: environment temperature, humidity and illumination of building are collected. The energy consumption (air conditioning equipment and lighting equipment) is embodied by the real-time representation of the environmental conditions of each building's use space.

Metering system: through the collection of energy consumption data of air conditioning, lighting, sockets, power, electricity and special power, the amount of energy consumed in buildings is measured by analogue measurement.

Control system: on the basis of measurement and detection, the results of measurement and measurement are compared and analyzed. Through building control system (BAS), intelligent optimization control of energy consumption equipment is carried out according to feedback control theory.

Analysis system: on the basis of appeal measurement and test database, a variety of energy consumption analysis reports and statements are provided, thus forming the basis for building energy efficiency reform.

In the aspect of energy saving, the system can detect the abnormal use of energy and adjust the running state of the equipment in time through real-time on-line monitoring, so as to ensure the comfort of the indoor environment, and eliminate the waste of energy. The system control process is shown in Fig. 2.

The system is divided into five layers, such as data monitoring and collection, data

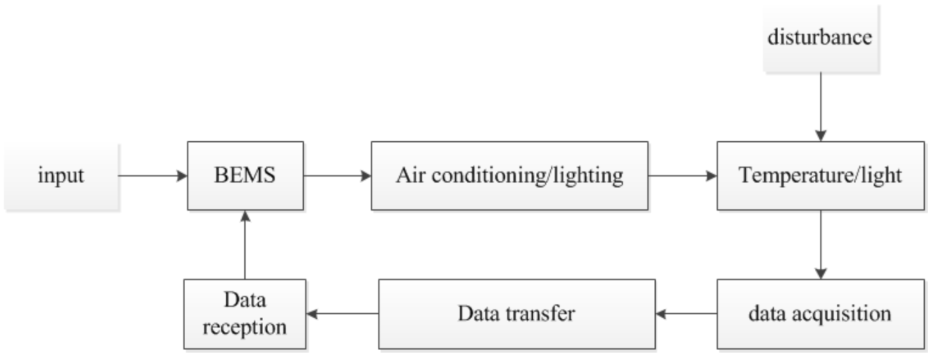

Fig. 2. BEMS system control flow chart

transmission, data interpretation, system evaluation and performance optimization, as shown in Table 2.

Table 2. Hierarchy of BEMS systems

The fifth layer	Energy-saving optimization layer	System operation optimization, parameter optimization, start stop, optimization and so on
The fourth layer	System evaluation layer	Building energy consumption analysis, energy saving potential assessment
The third layer	Data interpretation layer	Protocol interface development, data packet analysis, data storage
The second layer	Data transport layer	Zigbee, RS485 and other transport protocols
The first layer	Data acquisition layer	Environmental variables, equipment, electricity consumption and other energy information

The data acquisition layer is composed of three parts, namely, data acquisition subsystem, data transfer station, and data center, and the data acquisition subsystem is mainly responsible for monitoring and collecting energy consumption of the building facade, including an analysis software. The data relay station is responsible for receiving and caching the energy consumption information corresponding to the management area, and should upload it to the data center at the same time General data transfer stations can omit data processing and permanent storage capabilities. The data center is to receive and store the data information submitted by the transfer station in the corresponding management area, and then to display and publish it after processing.

In the process of gathering energy consumption data, two types are involved: the classified energy consumption and the sectional energy consumption. The classified energy consumption refers specifically to the type of energy consumed by state organs, office buildings and large public buildings, which is convenient to carry out data collection and arrangement, including power consumption, natural gas consumption, tap water consumption, etc. Based on the specific categories of building energy usage, there are 6 indicators for classifying energy consumption, including power consumption, water consumption, gas consumption, heating capacity, and cooling capacity and other energy consumption. For example, coal and oil are renewable energy sources. The sectional energy consumption refers to the amount of specific energy consumed by intelligent buildings in accordance with energy projects, which is convenient for data collection and arrangement on the basis of project use, such as lighting, electricity and power consumption, as shown in Table 3.

Table 3. Sampling of energy consumption data

Electricity for lighting outlet	A functional area in a building; all lighting
Electricity for air conditioning	A device for supplying air or warm air to a building. Generally speaking, the air conditioning electricity is composed of two parts, namely has two sub items, respectively, hot and cold stations, electricity and air-conditioning terminal power
Power consumption	All equipment that can provide power support, such as elevators, ventilators, pressure equipment, etc.
Special power consumption	Outside the building function of unconventional equipment, electricity, usually special electricity consumption is relatively large, and at the same time, concentration is relatively high

In the data transmission layer, data of sensors and meters are transmitted, and the data transmission mode is mainly divided into two ways: wire transmission and wireless transmission. In actual buildings, data transmission is still widely used for its stability and reliability.

Through the data collector, the data is stored in the relational database SQL Server in accordance with the required transmission mode. The friendly interaction in current intelligent energy management is to process data through the program and to display it through the application. The data is analyzed by the transmission command of the display layer, and the statistical data and parameter reports are obtained.

In the energy management system, 6 report modules are used, such as energy consumption report, energy consumption ranking, energy consumption comparison, monthly average report, deviation analysis, cost report and so on, so as to assess the use of energy.

Intelligent lighting and air conditioning systems are used as energy saving optimization systems. In the system, the fixed time switch is arranged on the intelligent lighting, so that the electric energy can't generate superfluous waste, and the energy saving target is achieved. Air-conditioning parameters are set up to ensure that temperature and humidity can be maintained within a certain value, so as not to waste energy. And the temperature of fresh air and return air is adjusted automatically according to temperature and humidity, so as to achieve the goal of energy saving.

4. Result analysis and discussion

After the development of the energy management system software, it was applied in the new office building of a design institute. Through the actual use of users, the system function indicators were tested, and the actual system data was used to test the system performance.

Firstly, some related reports in the system evaluation layer were obtained, as shown in Figs. 3 and 4.

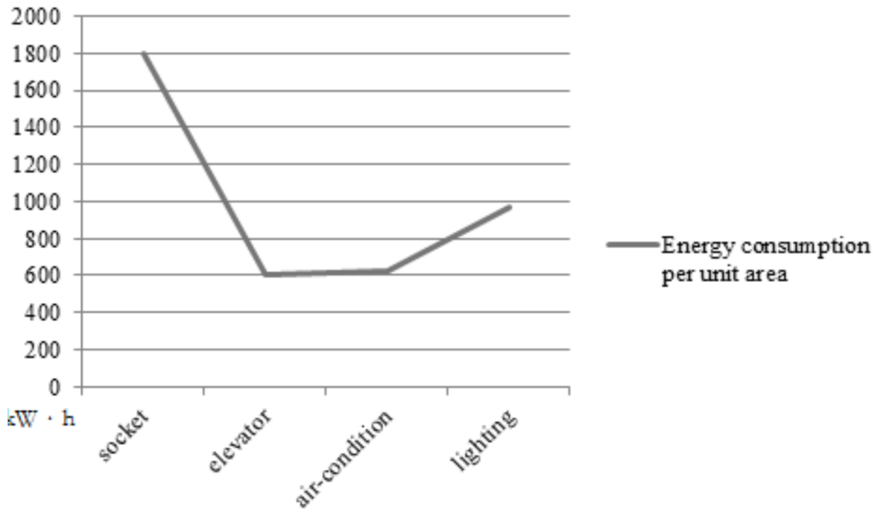

Fig. 3. Energy consumption report

Through the energy consumption report of energy management system produced on time, daily, monthly and annual, users can grasp all kinds of energy consumption. Through energy consumption indicators such as unit area, energy consumption and other indicators, the abnormal values of energy consumption can be found out. These energy consumption reports are also basic data supports for energy statistics and energy audits.

Energy ranking shows the energy consumption value of different equipment in each month, in which, the energy consumption can be observed in different months, and the energy consumption of different energy sources can be ranked. The energy efficient equipment and the lowest energy consumption equipment can be found through the energy consumption sequencing of the energy management team in different time ranges.

Secondly, the test of energy management system software was divided into 2 parts: function test and performance test. In functional testing, software integrity was the main test content, so as to test whether the software can meet the design goals, and whether the functions should to be implemented in the requirement analysis. In performance testing, the software's data processing time, space performance indicators were the main testing contents. And the function test was tested by manual operation. In the performance test, the actual data device was used for input and output tests, and the corresponding time consumption was calculated, and the results were obtained, as shown in Table 4 and Table 5.

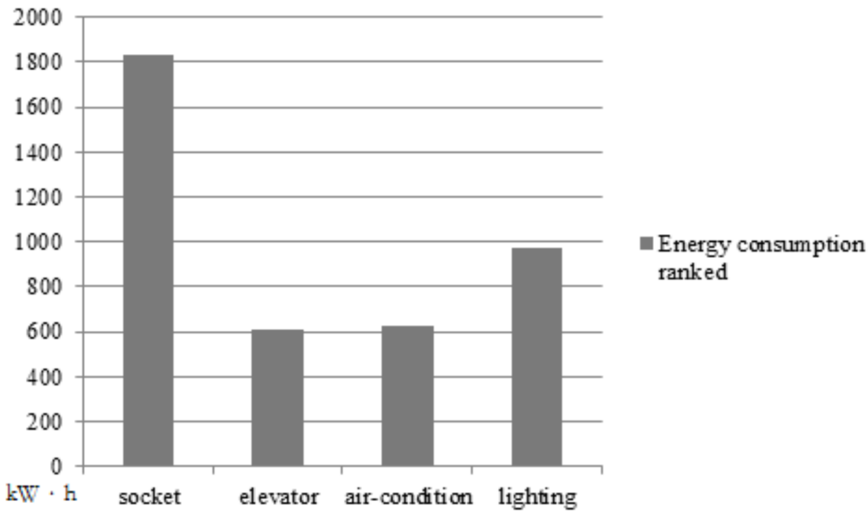

Fig. 4. Energy ranking

Table 4. Results of system function test

Test item	Test result
Monitoring the operation status of the main equipment in the energy system	Have
Setting energy system parameter function	Have
Centralized control, operation and adjustment of main equipment	Have
Comprehensive balance, reasonable allocation and optimized dispatching function of energy system	Have
Dealing with exceptions, failures, and accidents	Have
Basic energy data management function	Have
Real time short time archiving, database archiving and instant query function for actual data of energy operation	Have

Through the above tables, it can be seen that the building energy allocation is more flexible. The energy management system can change the energy allocation of buildings according to external conditions, energy supply, user demand and economic cost. The energy management system has many advantages, the first is to strengthen the energy system scalability, the energy management system can connect all the lower energy subsystems, and carry out comprehensive fault-tolerant control and energy use planning for all kinds of energy units in the building, which is easy to extend the system; the second is the openness of building energy systems, the energy management system is an open system, which makes the building energy system more convenient to connect with other building systems and exchange data, so as to achieve the purpose of integrated management; the third is the convenient management, energy management systems can save data and time on manual data acquisition, manual control, and error checking of building energy systems, while the non-professional managers can also master system manipulation in a very short period of time; the fourth is to improve energy saving effect, an obvious advantage of the energy management system can find the ideal energy consumption of each device through data analysis and control strategy design, and reasonably determine the set value of the running state of the equipment, automatically adjust the operation mode of equipment and control equipment start and stop time, so as to effectively reduce the energy consumption of building the system.

Table 5. Performance test results

Test item		Test result
1) System performance design index	Support simultaneous online customers	>10
	Number of connected control systems	>10
	The total number of control nodes in the connected control system	>20000
	The number of simultaneous changes in the number of control nodes in a connected control system	>500 dots per second
2) Time characteristic requirement	Client interface data updates (from the underlying device data update - changes in user interface data intervals)	<=5 s
	System real time data transfer time (the time delay from the underlying device data update - new data obtained by the system)	<=2 s
	System control command transfer time (refers to the user from the interface to send operation commands - the underlying device to accept the delay of the command)	<=5 s
	A storage record stored in a database (the time delay from which the underlying device data is updated - the system obtains new data from the device and stores it in the database)	<=5 s
	Update access to dynamic data	<=5 s
	All data in the system	<=60 s

5. Conclusion

Through the analysis of the control principle of central air-conditioning system for large building energy users, the core viewpoints of energy saving and energy efficiency improvement were derived in this paper. Starting from the whole, the central air-conditioning management system that can save energy and reduce energy consumption was analyzed, so as to realize the development of system energy consumption and system cold load, and the following conclusions were obtained.

Through the analysis of building energy management system, the general development of the system data interface was realized, the information storage function of the system was developed, the system software design was completed, and the purpose of reducing energy consumption was achieved. In this system, each parameter of the software was monitored in real time, and the processing and storage of the transmitted data were done at the same time. By referring to the parameter information and the control effect of the system, the relevant engineers analyzed the specific conditions of the system operation in a given time range, and calculated the utilization of the energy. And through the database comprehensive integration of energy use, the energy control strategy was optimized. In addition, real-time maintenance of the system was realized, and the related faults were inquired, thus providing important reference for solving the problem and optimizing the system.

However, there are still some deficiencies in the development of the system, and the application of the whole platform has not yet fully realized. Different projects should be improved. For example, in the future development, some of the following functions of the software can also be realized: the memory configuration of the database should be optimized, its use performance should be improved, a detailed design plan should be formulated, and the system should be tested, so as to realize the generalization of system interface, to integrate with other systems in the life, such as office system, parking management system and so on, thus promoting the all-round development of intelligent building.

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