Intelligent Building Equipment Control Technology and Energy Saving Analysis

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Abstract. In the process of rapid urbanization in China, the proportion of buildings' energy consumption is increasing, and the contradiction between energy and development is becoming increasingly prominent. On the basis of realizing its intelligent and comfortable goals, intelligent buildings have attracted wide attention from society due to their large operational performance. The research on energy saving of intelligent buildings has become an important direction for energy conservation research. The energy consumption of intelligent building equipment operation accounts for about 60% of energy consumption, which has become the main energy consumption object of intelligent buildings. This paper takes building equipment operation control as the research object, and introduces the energy saving ideas of building intelligent systems from the perspective of energy saving control, including energy saving control of building equipment, energy saving control of cold and heat sources, energy saving control of lighting, etc., and points out the future development direction of energy saving in intelligent buildings.

1. Introduction
With the advent of the information and knowledge economy era, modern architecture and information technology have infiltrated each other and organically combined to produce intelligent buildings. Based on the architecture of traditional buildings, intelligent building adopts computer technology, network technology, and automatic control technology. Through comprehensive system development, the building automation system (BAS), communication automation technology (CAS), office automation system (OAS) organically combined with building structure to provide people with safe, comfortable and energy-saving working and living space [1].

The world's first intelligent building was a City Place building in Hartford, Connecticut, built by United Technology Corporation's subsidiary, UTBS in January 1984. Ten years later, tens of thousands of "smart" office buildings, business centers, banks, etc. have risen rapidly in North America, Europe, and the Asia-Pacific region.

Since the 1990s, China has successively built a number of large intelligent public buildings in Beijing, Shanghai, Guangzhou, and Shenzhen. Most of them are commercial office buildings, and the most representative is Shanghai Pudong Jinmao Building. Intelligent building is a multi-disciplinary complex. People's requirements for indoor environmental quality are constantly increasing. In order to satisfy the needs of building use, a variety of building equipment systems have been added to the building. Figure 1 is a classification diagram of intelligent building equipment systems, focusing on a variety of building equipment such as building water supply and drainage, building heating, air conditioning, building power supply and distribution, and building lighting. Building equipment is the
foundation for intelligent buildings to achieve intelligent, safe, comfortable, and convenient operation, and it is also a key research object for energy saving in intelligent buildings.

In the energy consumption of intelligent buildings, the energy consumption of various types of equipment accounts for a major part. According to statistics, China’s building energy consumption accounts for more than 30% of the total social energy consumption \(^2\), of which 50% - 60% of energy consumption is used for cooling or heating of buildings \(^3\). Figure 2 shows the energy consumption distribution of office equipment. As can be seen from the figure, the operating energy consumption of the air conditioning system accounts for 37% of the total energy consumption in the building. According to the calculation of the Shanghai Museum after adopting intelligent buildings, it can save 6 million yuan in electricity and gas costs each year, saving more than 60% \(^4\). Therefore, in order to ensure comfortable environment conditions, save energy consumption and reduce the operating costs of air conditioning systems, relevant measures should be taken to reduce energy consumption.

2. Energy saving control of construction equipment in intelligent buildings

2.1. Mechanical and electrical equipment start-stop optimization control

In traditional buildings, the start-up and operation of electromechanical equipment consume a large amount of electrical energy, and the electricity consumption occupies a large proportion. Therefore, BAS needs to control the operation of electromechanical equipment in the entire building to achieve the best operating results. BAS has the best startup time control software for electromechanical equipment, which can ensure that the indoor temperature just reaches the set value when workers enter the building. It can ensure that the comfort requirements can be met from the beginning of the entry time, reduce the excessively long startup time, and perform optimal time control on multiple devices at the same time. Its control algorithm is implemented by software, and has a strong function of...
automatically adjusting the optimal startup time according to changes in environmental conditions. The optimal stop time control program is similar to the principle of the optimal start time control program. It also uses the principle of inertial energy storage, which enables the heating or cooling load to use hot or cold inertia for a period of time. And before reaching target temperature, system stops heating or cooling in advance, while ensuring that the ambient temperature does not exceed the comfort limit. Except for some air-conditioning systems that must run continuously, the most direct way to save energy is to shut down needless equipment. Due to the large thermal inertia of the air-conditioning area, it can automatically start the air-conditioning unit before work and the earliest shutdown of the air-conditioning unit before work to achieve the most satisfactory conditions under the conditions of comfort, achieve the optimal on-off control and maximum energy saving. Starting and stopping of electromechanical equipment can also be automatically controlled by adjusting the time required for equipment preheating or cooling according to weather conditions.

2.2. Partial load water pump for air conditioning in winter and summer

During the operation period of air conditioning, the air conditioning load varies greatly with the seasons. The operating time is very short under the calculated rated load condition, and most of the time the air-conditioning equipment is operating far below the rated value. From the summer air-conditioning load time frequency provided in Table 1, it can be seen that 83.8% of the operating time is operating under a load of less than 50%. When heating is provided in winter, about 80% of the operating time load is less than 40%.

| Load rate (%) | 5  | 10 | 15 | 20 | 25 | 30 | 35 | 40 | 45 | 50 |
|---------------|----|----|----|----|----|----|----|----|----|----|
| Time (%)      | 12.2 | 6.5 | 11.4 | 12.2 | 8.9 | 7.6 | 7.7 | 7.2 | 5.5 | 4.6 |
| The cumulative time (%) | 12.2 | 18.7 | 30.1 | 42.3 | 51.2 | 58.8 | 66.5 | 73.7 | 79.2 | 83.8 |

| Load rate (%) | 55 | 60 | 65 | 70 | 75 | 80 | 85 | 90 | 95 | 100 |
|---------------|----|----|----|----|----|----|----|----|----|-----|
| Time (%)      | 4  | 3.3 | 2.5 | 2.2 | 1.7 | 1.2 | 0.7 | 0.3 | 0.2 | 0.1 |
| The cumulative time (%) | 87.8 | 91.1 | 93.6 | 95.8 | 97.5 | 98.7 | 99.4 | 99.7 | 99.9 | 100 |

Because the flow and system resistance of air-conditioning water systems in winter and summer seasons are very different, for two-regulated air-conditioning water systems in large and medium-sized projects, in accordance with the current "Code for Design of Heating Ventilation and Air Conditioning of Civil Buildings" GB50736-2012, it is appropriate to set cold water circulation pump and hot water circulation pump separately. This is because for multi-storey or high-rise civil buildings, the temperature difference between supply and return water in summer is 5 °C, and the temperature difference between supply and return water in winter is 10 °C (the temperature difference between supply and return water in winter is about twice that in summer). Generally, the air conditioning heating load in winter is smaller than the air conditioning cooling load in summer in the southern region (the winter heat load in the northern cold region is greater than the summer cooling load). Therefore, the water flow rate required by the system in winter condition is about half of that in summer condition. If the circulation pump is used in winter and summer, the circulation pump is generally selected according to the cooling operation conditions of the system. During heating operation, the system and the pump conditions do not match, which often makes the pump unable to operate in the high-efficiency zone or the system. The operation results in a small temperature difference and a large flow, and also causes waste of electrical energy. So, the circulation pumps should be set separately, and the low-head pumps running in winter conditions can be activated under partial load conditions in summer and can also be switched through the valve. Therefore, it is not necessary to provide additional water pumps at partial loads, which saves investment and the initial investment of the system can be quickly taken back.
2.3. Optimal Control of VAV System
The Variable Air Volume air conditioning system operates under low load and its energy saving effect is much better than the Constant Air Volume system. Under conventional control, the system controls the supply air temperature of the VAV to remain unchanged. When the area is under partial load, the air supply volume of the VAV is reduced, which reduces the energy consumption of the air supply fan.

Using the optimization of HVAC control in the BAS control system, the emphasis is on analyzing the advantages and disadvantages of VAV and VRV and proposing an optimization scheme. In HVAC systems, there is a large amount of fresh air and supply and exhaust air work. Energy conservation optimization should take this into consideration first. Therefore, it is necessary to use DDC controllers to replace daily operation and maintenance on the premise of ensuring normal operation, which can greatly reduce equipment damage and runaway control. In intelligent buildings, to optimize the VAV system, firstly we need to find the best parameter matching for the system operation, and secondly is to perform state simulation (quantification) on the system's operation process, simplify the control link, and improve the system response speed.

In addition, according to the operating characteristics of the variable air volume air conditioning system, when calculating the total load of the air conditioning system, the simultaneous use factor of each room can also be considered to reduce the installed capacity of the fan. According to different working conditions in winter and summer, the return air temperature is monitored, and compared with the set temperature value, based on the difference between the return air temperature and the set temperature, the cold/hot water valve is processed with different PID adjustment, so that the indoor temperature is always kept within the set range.

2.4. Fan coil energy saving control
At present, there are two main methods for controlling the fan coil system, namely air volume adjustment and water volume adjustment. Generally, in air volume adjustment, single-phase three-speed variable-speed motor is used. The fan's air volume is controlled with the three levels of high, medium, and low. Water volume regulation mainly adopts indoor temperature sensors and controllers to control the opening of electric two-way valves and adjust the flow of cold/hot water through the coil tube to achieve the purpose of temperature control [5].

In the intelligent automatic control of fan-coil, the fan-coil network management and control system is established under the condition of satisfying the indoor temperature, three-speed wind speed regulation and on-site control of cold and warm switches. We should choose the large temperature difference type fan coil units and networking fan coil thermostat (temperature controller can be realized through the gateway device connected to the Internet, to accept the central monitoring system of unified monitoring and management), using intelligent monitoring and control procedures, collecting fan coil sensor parameters such as temperature and fan speed by region, loop backing them to the system via the network of workstations, through the computer processing system, carrying on the management control based on the program setting.

3. Energy-saving control of cold and heat sources in intelligent buildings

3.1. Optimization and optimization of cold and heat source equipment
Since the energy consumption of cold and heat source equipment accounts for a large proportion in the air conditioning system, reducing its energy consumption is one of the important contents of energy saving in air conditioning. The main way to reduce the energy consumption of cold and heat source equipment is to optimize the cold and heat source equipment. The optimized configuration of equipment refers to the most suitable unit selection and configuration under specific conditions such as the energy structure and system load characteristics of the project area. Equipment selection depends on two parameters: one is the performance parameter COP of the chiller or heat pump unit; the other is its comprehensive partial load performance coefficient IPLV. The selected unit must pass various safety and technical performance test verifications, and the above two indicators are larger than the
allowable minimum equipment.

All refrigeration unit configurations can use start/stop and related load control interlocks, and users can modify and set parameters and interlock points in the interlock control program according to the specific conditions of the site. We need to calculate the cooling load of the air-conditioning system based on the temperature difference and flow of the water supply and return water, and submit an application for start/stop control to the refrigeration unit control system based on the actual cooling capacity of the unit to realize the coordinated control of chiller unit, chilled water pump, cooling water pump, cooling tower fan, cooling tower water inlet valve and other equipment, and at the same time, monitor the running status and fault status of the unit.

3.2. Utilization of new energy

The use of system energy includes the use of renewable energy such as solar energy, geothermal, seawater, river water, and lake water. The use of geothermal energy and solar energy will be increased through collection equipment and energy storage equipment.

There are three ways for humans to use solar energy: photothermal conversion, photoelectric conversion and actinic conversion. The use of solar energy in HVAC are mainly two in the past. Solar air-conditioning system is a light-to-heat conversion system. This system uses the heat energy collected by the collector directly, so it is more efficient. If the solar cooling system is compared with a conventional electric refrigeration system, it can be found that the former saves the energy wasted when converting thermal energy into electrical energy.

Optimize energy storage systems. Heat storage and cold storage are two key systems that HVAC plays a role in regulating indoor temperature in intelligent buildings. Energy consumption accounts for a relatively large amount, so the optimization of the energy storage system must be considered first. In terms of cold storage, the “series and parallel” method can be considered in the design, which is more conducive to the storage and full use of cold energy. In terms of heat storage, the focus should be on water heating, and a heating system with low energy consumption should be selected.

4. Conclusion

The equipment system is the material carrier of the intelligent building. The realization of the intelligent function target system in intelligent building depends on the selection, integration, usage, maintenance, and management of various types equipment, which is an important part of the intelligent building and the foundation of building intelligence. Therefore, equipment and automation systems are the foundation for intelligent buildings to realize intelligent functions and the main development direction of building energy efficiency. From the above, it can be concluded that in the entire intelligent building, optimal control of air-conditioning systems, optimal on-off of electromechanical equipment, VAV air-conditioning systems, optimization and configuration of cold and heat sources, and the use of new energy will be important development directions for the building energy conservation.

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