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Research on Optimal Design for Water Supply and Energy Conservation in High-rise Office Buildings

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Abstract

The energy conservation in high-rise office buildings is a key project of building energy conservation work in China. Based on the actual need of projects and with the water environment intelligent monitoring system of photovoltaic power generation as the core, this paper conducts the intelligent and informatization management to the water supply and drainage of high-rise office buildings. Based on the data specification of water supply and drainage design of sanitary ware in China, square-root method is used to design the traffic system, and the rainwater comprehensive utilization system is introduced by referring the advanced experience in China. With shaft power and efficiency index, the superiority of double-pump parallel frequency conversion in the water tank - pump frequency conversion water supply in high-rise office buildings, which provides reference and data base for the subsequent engineering practice and has certain engineering application value.

Keywords*: High-rise office building; Water supply and energy conservation; Intelligent monitoring of water environment; Double-pump parallel frequency conversion*

1. Introduction

Currently, the energy consumption of public buildings accounts for 11.4% of the world's total energy consumption, and energy consumption of high-rise office buildings accounts for nearly 20% of the energy consumption of public buildings. The latest statistics show that the total area of high-rise office buildings in China is about 890 million square meters, and the total power consumption is about 172.6 billion KWH. Besides, with the rapid development of national economy, the total area of high-rise office buildings increase rapidly and the power consumption also further increased. Therefore, the Ministry of Finance and Ministry of Housing and Urban-Rural Development have explicitly included the high-rise office building energy conservation as one of the key in the building energy conservation work during "the 12th Five-Year Plan" to actively promote and implement the energy-saving renovation work of high-rise office buildings and strive to control the situation of high energy consumption of high-rise office buildings. Based on the design requirements for energy conservation of high-rise office buildings and with the intelligent monitoring system of water environment as the core, this paper explores and optimizes the designs of photovoltaic power generation, water supply and drainage flow, rainwater collection and utilization, secondary water supply design and other aspects, providing a reference for the engineering design.

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2. The Design of Water Environment Intelligent Monitoring System

Water environment intelligent monitoring system, a gradually mature new building design formed with the development of computer and electronic technology, uses solar energy, the environmental friendly and renewable green energy, to carry out the information real-time monitoring to the water consumption in high-rise office buildings, apply the green energy technology in the information management, and improve the energy-saving control ability in high-rise office buildings.

As shown in Figure 1, water environment intelligent monitoring system mainly includes the central computer management system, power consumption management system, building water environment system, database system, integrated wiring management system, network controller, field controller and other parts. The building water environment system is the heart of the water environment intelligent monitoring system, mainly including water supply subsystem, drainage subsystem, reclaimed water subsystem, direct drinking water subsystem, and rainwater subsystem, etc. The various subsystems run independently but supplement each other. The system can conduct the centralized management and real-time monitoring and save water resource, which is of great significance for the water supply energy conservation in high-rise office buildings.

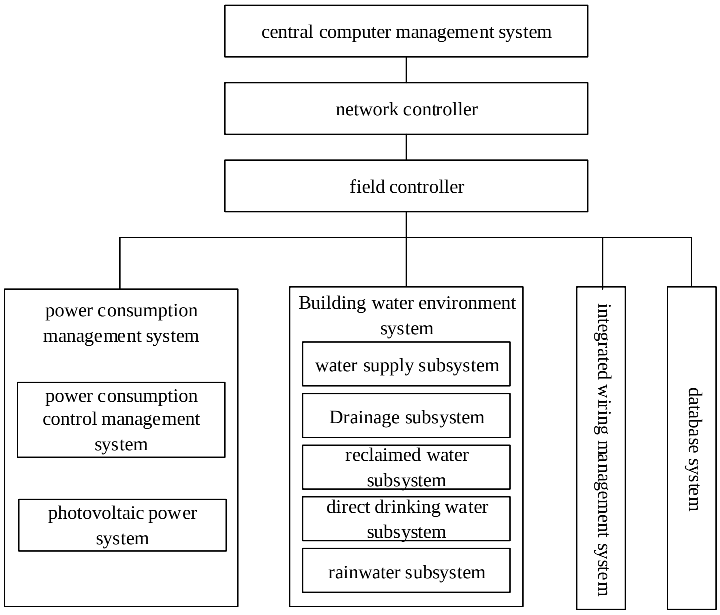

Figure 1. The Composition of Intelligent Monitoring System of Water Environment

Power consumption management system is the energy source of intelligent monitoring system of water environment, which mainly uses solar energy to supply power. The hardware part consists of charge and discharge controller, storage battery, inverter, DC/DC converter, etc. The hardware structure is shown in Figure 2. This system can store and convert the direct current output by the solar cell, and supply it to the intelligent monitoring system of water environment. The electricity for equipment of the water environment intelligent monitoring system is divided into AC load and DC load. The AC load is connected to the inverter and the DC load is connected to the DC/DC converter.

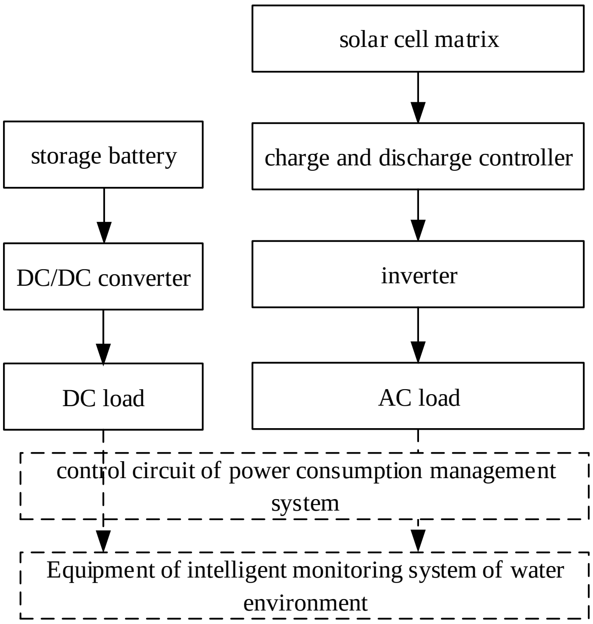

Figure 2. Hardware Structure of Power Consumption Management System

3. Optimization of Water Supply and Drainage Design

3.1. Flow Design

In high-rise office buildings, water consumption can present certain characteristics in different time periods. For example, the water consumption in the daytime is higher than that at night, the water consumption in working day is higher than that in holidays, and the water consumption in rest time is higher than that in working time, the distribution of water consumption in different periods is uneven. In order to alleviate the pressure at water consumption peak, the water flow value should be determined to ensure the water demands. The common calculation methods of water flow include percentage method, square-root method and hunter curve method, etc. This system uses the square-root method with public toilets as example, and the design formula of flow per second is as shown in formula (1).

$$q_k = 0.2 \cdot a \cdot \sqrt{N_g} \quad (1)$$

Where q_k refers to the flow per second of water supply design of the designed pipe section, and N_g refers to the water supply equivalent number of the sanitary ware in the pipe section; a is drainage equivalent, which varies with usages of different ware, and the flow coefficient of public toilets is 3.0. It is important to note that when the calculated value is greater than the cumulative flow value of rated water supply flow of the sanitary ware, the latter should be adopted;

Based on this, the calculation formula of design flow per second q_p of the drainage pipeline of high-rise office buildings is as formula (2):

$$q_{\mathrm{p}} = \sum_{i=1}^{m} q_{ki} \cdot n_{0i} \cdot b_i \quad (2)$$

Table 1. The Design Data of Sanitary Ware Water Supply and Drainage

Sanitary ware	Drainage flow (l/s)	Drainage percent (%)	Drainage equivalent
Hand basin	0.1	50	0.3
Time-lapse self-closing flush valve of toilet bowl	1.2	10	3.6
Urinal time-lapse self-closing flush valve	0.1	50	0.75

After calculating the design flow per second of water use according to formula (1) and formula (2), rules should be set for the corresponding design flow, which is set in 3.3.5 of the Design of Water Supply and Drainage of Buildings: After calculating the design flow per second of water use according to formula (1) and formula (2), rules should be set for the corresponding design flow, which is set in 3.3.5 of the Design of Water Supply and Drainage of Buildings: After calculating the design flow per second of water use according to formula (1) and formula (2), rules should be set for the corresponding design flow, which is set in 3.3.5 of the Design of Water Supply and Drainage of Buildings:

3.2. Rainwater Collection and Utilization

Urban rainwater usually has three converge medium: roof, road, and greenbelt. According to the water quality monitoring result by the relevant research teams in China, the quality of road rainwater is relatively bad, and COD in the early rainwater can reach up to 3000-4000 mg/l; The rainwater runoff of greenbelt is mainly through penetration, and the collected rainwater amount is less; relatively, the quality of rainwater on roof is better and runoff is bigger, which has the highest collection value. According to the experience of developed Europe and the American countries, rainwater collection design includes two categories: (1) collect the rainwater on roofs and runoff water on green space and roads for greening, washing and recycling after treatment; (2) the rainwater on roofs and overflow water on roads seeping into the collecting sump below the green space can be used to supplement water and plant evapotranspiration, and the excessive water can be pumped out for anther usages. The design structure of rainwater collection and utilization is shown in Figure 3. The collected rainwater is drained into municipal pipe network through the initial split-flow equipment, which can avoid the effect of pollutants in initial runoff on the environment, and improve the purification efficiency in the subsequent water treatment. The treated rainwater can be used for the irrigation of green space near the buildings and washing the roads. When the rainfall is larger, the redundant rainwater can be directly discharged into the municipal pipe network. Thus, we can reasonably use the natural water resources and reduce the water consumption of drinking water. In Shanghai, for example, the total annual precipitation is 1149.8 mm, which has a considerable saving benefit.

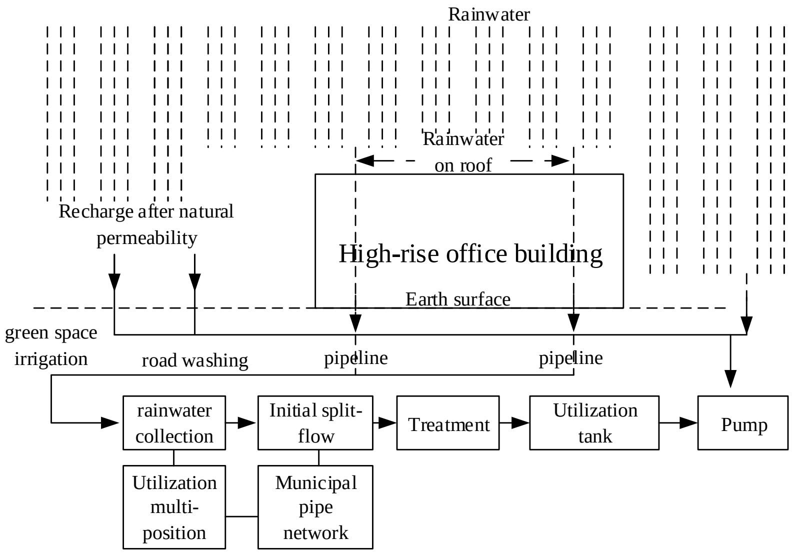

Figure 3. Rainwater Collection and Utilization

4. Energy Saving Optimization Design Research on Secondary Water Supply

Because the pressure of municipal network water supply cannot meet the pressure requirement in higher floors of high-rise office buildings, the secondary water supply system is needed. This design scheme mainly uses the water tank - pump frequency conversion water supply mode, which realizes the frequency control water supply by using frequency converter and microcomputer to control the pump according to the parameter variation of actual water consumption. The design consists of water tank, pump, pressure sensor, control cabinet, water distribution network and water consuming points. As shown in Figure 4, this design mainly uses the constant pressure control mode. By controlling the pressure sensor installed in the outlet-side of pump to make the pressure at the outlet of the pump remain unchanged when the system is running.

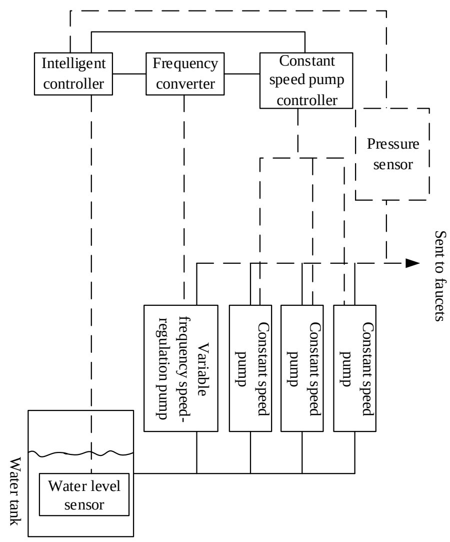

Figure 4. Structure of Water Tank - Pump Frequency Conversion Water Supply

Reasonable water supply method has a significant role in reducing the energy consumption of the pumping set in high-rise buildings. In the actual work, parallel operation of multiple pumping sets are the main method, we need to improve the running efficiency of pumping set in parallel connection. J7

For the pump, if flow - head characteristic curve fitting order is 2, the flow - efficiency characteristic curve fitting order is 2, and the flow - shaft power characteristic curve fitting order is 1, high fitting precision can be get. The fitting expression of the three characteristic curves is:

$$\mathrm{H} = a_0 \cdot Q^2 + a_1 \cdot Q + a_2 \quad (3)$$

$$\eta = b_0 \cdot Q^2 + b_1 \cdot Q + b_2 \quad (4)$$

$$N = c_0 \cdot Q + c_1 \quad (5)$$

In the formula, *Q* is pump flow, *H* is pump head, is pump efficiency, *N* is pump shaft power, *a*, *b*, *c* are polynomial fitting coefficients.

Where Formula (3), (4) and (5) are the operating characterist*ic of* the pump at the rated speed n_0. For the frequency control pump, operating characteristic at non rated speed should be fitted. The characteristic curve at any speed *n* can be obtained by using the golden rule to convert the Formula (3), (4) and (5).

$$\frac{Q}{Q_0} = \sqrt{\frac{H}{H_0}} = \sqrt[3]{\frac{N}{N_0}} = \frac{n}{n_0} \quad (6)$$

The characteristic curve at any speed n:

$$\mathrm{H} = a_0 \cdot Q^2 + a_1 \cdot \mathrm{K} \cdot Q + a_2 \cdot K^2 \quad (7)$$

$$\eta = b_0 \cdot \left(\frac{Q}{K}\right)^2 + b_1 \cdot \left(\frac{Q}{K}\right) + b_2 \quad (8)$$

$$N = c_0 \cdot K^2 \cdot Q + c_1 \cdot K^3 \quad (9)$$

$$K = \frac{n}{n_0} \quad (10)$$

Where, Q_0 is the rated flow of pump, n_0 is the rated speed of pump, n_0 is the actual speed of pump, and K is the ratio of the actual shaft speed and rated speed of pump.

Study has found that when the operation flow is less than the rated flow of a pump, constant pressure frequency conversion water supply is better than the frequency pump whether in efficiency or energy consumption. When the running flow is greater than the rated flow of a water pump, though the pump is still running in high efficiency range, long time overload will cause substantial damage to the pump. Therefore, parallel operation with two or more pumps should be used in the practical engineering.

When the operation flow of a pump is greater than the rated flow but less than the rated flow of two pumps, there are two kinds of running programs: one pump adopts power frequency operation and other pump uses variable frequency operation, or both pumps adopt variable frequency operation. The operation shaft power curve with two parallel variable frequency pumps is as shown in Figure 5. In Figure 5, line AC represents the plan with one power frequency pump and one variable frequency pump. The shaft power of the power frequency pump is 2.48 kW, the shaft power of the variable frequency pump is 1.27 kW, and the average power of both pumps is 1.88 kW. Line DF represents the plan with two variable frequency pumps, and the shaft power of which is 1.66 kW, which is 0.22kW lower than plan with one power frequency pump and one variable frequency pump. Meanwhile, the plan with two plan variable frequency pumps is 4.38% higher than the plan with one power frequency pump and one variable frequency pump. Therefore, the two pumps in the design are both variable frequency operations.

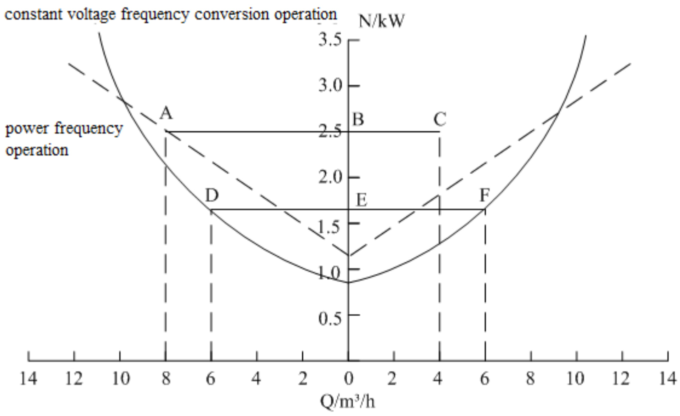

Figure 5 The Shaft Power Curve of Parallel Operation of Pumping Set with the Same Type

5. Conclusion

Due to the uniqueness of water consumption in time period and ware, the energy conservation optimization of water supply of high-rise office buildings also has certain particularity. Based on the actual engineering demand and with the green information intelligent monitoring system powered by photovoltaic power generation of high-level office buildings as the core,

This paper discusses and optimizes the drainage optimization schemes such as flow design and rainwater comprehensive utilization in engineering as well as the water supply scheme of multiple-pump parallel variable frequency in the energy conservation of the secondary water supply, provides reference and thinking for the engineering practice of energy conservation of water supply in high-rise office buildings, gradually applies the application research results in the subsequent construction, and strive to promote the energy conservation optimization of water supply in high-rise office buildings to a new level.

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