Study on the energy saving model optimization of HVAC control system based on the whole life cycle theory

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Abstract

HVAC (Heating, Ventilation and Air Conditioning) is the heating, ventilation and air conditioning equipment widely used in construction engineering. Its operation effect can support the conditioning of the whole temperature and humidity in the building, and thus achieve the room temperature environment suitable for the living of the human beings. Though HVAC system has the important functions, such as air quality and temperature conditioning, it is characterized by high energy consumption in fact, which has had severe impact on the sustainable development goal of ecological and environmental protection. For this reason, this study has designed the model optimization scheme of HVAC control system energy saving, and has raised the corresponding optimization method and design goal through analyzing the HVAC energy saving demand for environmental protection, and defining the whole life cycle evaluation indexes. It aims to meet the final claim of energy saving and environmental protection, reduce the energy consumption of HVAC system through the optimization model design of HVAC control system energy saving, and provide the theoretical reference for the related study.

Keywords: Whole Life Cycle, HVAC, Variable Frequency Technology, Enclosure, Cold and Heat Energy Recovery.

1. STUDY BACKGROUND

1.1 Literature overview

HVAC is the air conditioner integrating the regulating of air supply, ventilation and heating functions. HVAC system is designed with the use of thermodynamics, fluid dynamics and fluid mechanics, and is an important subdiscipline in the mechanical engineering field (Qi and Guo, 2017). HVAC system effectively controls the important air circulation indexes, such as temperature and humidity, in the building, thus creating high comfort for the living environment of the human beings. Therefore, HVAC system has been widely used in the medium and large-sized buildings (Wang and Tang, 2017). But this system will generate certain resource wasting due to too high demand for heat energy during the operation. Therefore, the key technical study on HVAC system now focuses on the energy saving. Related studies have shown that, the analysis on the energy saving criteria of HVAC system based on the whole life cycle theory of the building can effectively avoid too high heat energy consumption (Wang and Xu, 2017). Therefore, exploring the HVAC control system energy saving model with the whole life cycle theory is also the main direction for the technical improvement.

1.2 Study objective

HVAC system is designed with the use of thermodynamics, fluid dynamics and fluid mechanics, and is an important subdiscipline in the mechanical engineering field. While the whole life cycle was initially used in the market transaction level, and its core concept was based on the judgment on the natural regulating capacity of economic environment and the locking of the optimization direction (Jin and Shao, 2017). While in recent years, every stage of the architectural link has been evaluated with the whole life cycle in the construction industry, which is also the practice direction for improving the system building model. In the optimization design of HVAC system, it is required to make comprehensive measurement of the applicability and construction criteria of the building, and then the classification of the design schemes with the measurement dimensions of whole life cycle theory is also more targeted (Li et al., 2016). In addition, energy saving is also the mainstream application direction designed in the use dimension of the whole life cycle, then the control of the resource consumption shall be based on the whole life cycle theory, thus assessing the actual effect of HVAC control system in energy saving. For this reason, this study has analyzed the reference variables of HVAC in air supply, ventilation and heating based on...
the whole life cycle theory, and raised the optimization and regulating scheme, to meet the demand for energy saving and environmental protection for the air conditioners in the use stage.

2. ANALYSIS ON HVAC ENERGY SAVING DEMAND FOR ENVIRONMENTAL PROTECTION

2.1 Key points in energy saving and intensive development

Energy problem does not happen only in China, and with frequent development of multiple resources worldwide, the proportion of energy consumption has been far beyond the basis of the social development nowadays. While HVAC is one of the largest energy consumption projects. The related reports have shown that among total energy consumption in the construction industry in China, the air conditioning and heating energy consumption accounts for the highest percentage, having been up to 42.85% of total energy consumption in the buildings (Leng and Zhu, 2015). Though HVAC can improve the living environment in the buildings very largely, it will easily result in the excessive wasting of the ecological resources at the cost of the energy consumption, and even accumulate and push the energy consumption of the buildings in subsequent operation, resulting in the energy consumption percentage in China cannot interface with the demand for environmental protection of the ecological resources, and incurring the intangible economic cost and resource cost pressure. So, the all-new HVAC control system capable of saving primary energy has become the major focus in the air-conditioning study, and also represents the final claim based on the key points of energy saving and intensive development.

2.2 Demand for the technical conditions of environmental protection

Usually, the heat sources for HVAC system include thermal power station, heat pump, small-sized boiler, regional boiler room, and direct-fired lithium bromide absorption-type water heater. Among all key technologies in current use, it is unavoidable to encounter the adverse impacts, such as atmospheric pollution or ozone depletion, and even greenhouse gas effect and air quality worsening. Hydrocarbon refrigerant is one of the environmental protection technologies under attention, having achieved the practicable effect of energy saving over 35% in actual use by comparison with that of R134 and R22 air-conditioners (Dong and Hou, 2013). In addition, hydrocarbon refrigerant belongs to the natural working fluid with low emission of carbon monoxide. So it is one of the operation systems with the best operation effect. Nowadays, Vice Minister Li Ganjie of Environmental Protection has given the affirmation to the hydrocarbon refrigerant room air conditioner project in the Sino-German cooperation. While in Zhuhai City, Guangdong Province, the project acceptance has been smoothly finished, which indicates that the hydrocarbon refrigerant has certain application value. But there is still high demand for environmental protection, and the design of the demand for environmental protection of HVAC system to the theoretical lower limit is the highest goal of demand for environmental protection. For this reason, it is required to optimize the HVAC control system, and achieve the expected environmental protection effect of the whole life cycle.

3. DEFINITION OF WHOLE LIFE CYCLE EVALUATION INDEXES OF HVAC SYSTEM ENERGY SAVING MODEL

For the evaluation indexes of HVAC system energy saving model in the whole life cycle, it is required to take the total energy consumption of the building as the quota reference, and obtain the optimization direction for energy saving of HVAC system from the proportion of overall energy consumption. For HVAC equipment, the total energy consumption in the life cycle needs the measurement of the energy consumption of the air conditioning system, the energy consumption for the heating demand in the building, and the energy consumption known for final scrapping and disposal (Guo et al., 2014). All factors influencing the energy consumption are included into the scope of consideration in the whole life cycle, then it is possible to adjust the system regulating means based on the optimization direction. According to the whole life cycle theory, the energy consumption of the building itself can be used with different consideration items in the use stages of the air conditioning device.

First, the energy consumption of HVAC system in the production, use, scrapping and dismantling is used as the first scope of survey. Second, based on the floor area, annual total energy consumption of the building, and the energy consumption and emission index in the unit area, as the second dimension of survey in the evaluation conditions. Third, taking the material categories and application of the HVAC system in the assembly of the components as the survey items in the initial stage, accurately calculate the energy consumption value of HVAC in the production and installation stage, thus creating the third scope of survey indexes for the evaluation conditions (Han et al., 2014). Finally, evaluate CO2 emission of HVAC in the whole use period based on the energy saving demand for environmental protection in the whole life cycle, thus define the ratio of hazardous
substances in the enclosure list, as the fourth survey condition. Based on the four indexes with survey and evaluation, this study defines it as $S(u)=(u_1,u_2,u_3,u_4)$ set, for the evaluation of the fulfillment conditions and achieving degree of the indexes. The operation model is:

$$S'(u) = \sum_{i=1}^{n} \frac{U_i \times 1000}{Q \times L_{co2} / S}$$

In this formula, $U_j$ represents the achieving degree of these four energy saving indexes in the $j$th time node in the whole life cycle, $L_{co2}$ represents the survey threshold of CO2 emission, taking the optimal status in the $i$th time node as the optimization reference of the current energy saving indexes, for accurate evaluation whether the energy saving conditions of the four specific indexes are met, to provide the theoretical parameters for the reference criteria of the whole life cycle.

4. MODEL OPTIMIZATION DESIGN OF HVAC CONTROL SYSTEM ENERGY SAVING BASED ON WHOLE LIFE CYCLE THEORY

The preliminary optimization is made on the HVAC control system in current use, classified into the optimization in enclosure improvement and system equipment improvement (Zhang and Gu, 2013). The overall structure framework of optimization design is shown in Figure 1.

![Figure 1. The Overall Structure Framework of the Energy Saving Mode Optimization System of HVAC Control System Based on the Whole Life Period Theory](image-url)

4.1 Enclosure optimization design

In the optimization design of the enclosure, the partial structures, such as wall, roof and window, are adjusted. Since the exterior wall has high heat storage demanded for the building, it is possible to control the temperature on the wall surface after the use of the absorptive heat insulation technology and reflective insulation technology. When the heat insulation layer reaches the expected heat insulation effect, HVAC control system is not required to provide excessive heat energy. So it can have certain effect of energy saving and environmental protection (Bai et al., 2014). In this respect, it mainly involves the adjustment of the smoothness of the exterior wall applied with light-color coatings, or creating the insulating space by using the heat storage coefficient in external heat insulation technology and internal heat insulation technology. Some studies have provided the optimization scheme that the vegetation absorbs the solar radiation, which can have certain evaporation heat diffusion and heat energy storage effect. In addition, it is possible to update the building design demand, and properly adjust the window functions, for example, replacing it with the energy saving window, or changing the single-layer window in the two-layer window, and using the sun-shading window.

4.2 Improvement design of system equipment

The enclosure is the optimization direction for the design based on the energy saving demand of the equipment and system, and after making use of the heating means in the building itself, it is possible to achieve the expected
energy saving effect through the optimization of the air-conditioning heating system in the public space. This involves heat recovery technology, reduction of heat medium, and inverter air conditioner technology.

First, the optimization design direction of cold and heat energy recovery is the optimization direction designed according to the integration of the energy recovery effect of the air conditioning system (Zhang et al., 2014). The study on the HVAC system with respect to cold and heat energy recovery has never stopped. Using the exhaust air heat recovery technology, it is possible to convert the exhaust air energy according to the geographic advantages of the building, then preheat or precool the fresh air as the optimization treatment. Then the fresh air will have relatively reduced load when being supplied, thus achieving the expected energy saving effect. While the completion of the exhaust air heat recovery needs the joint support of the total heat recovery system and sensible heat recovery system. The recovery equipment can achieve the final goal of optimizing the energy collection items by taking the warping-type total heat exchanger as the fundamental equipment, taking the runner-type total heat exchanger as the work item for energy collection in the time interval, and finally using the plate-type sensible heat exchanger to convey the heat energy.

Second, the optimization design for reducing the heat medium is the optimization scheme after mainly considering the energy consumption level in the use period of HVAC system. Its design scheme is the optimization model designed to reduce the heat medium conveying barrier, and it is required to reach the optimization goal through the integration of the operation status, and form the comprehensive energy saving system. The heat medium transfer usually includes the heat energy transfer means and the selection of the design materials, such as the grouped equipment components (including the heat insulating materials and buried pipes), and the prefabricated insulating devices capable of achieving the hot water circulation treatment (Zhao et al., 2011). The expected energy saving indexes are met while reducing the heat energy transfer exhaustion. Besides, it is possible to use the computer system for the optimization and adjustment of the heating conditions, build the unified survey data of the pipe network flow by using the optimized configuration of balanced valve and intelligent pipe network, and interface it with the central processing system, to achieve the energy saving goal in high-efficiency operation. For the implementation of the energy saving design in the air-conditioning system, it is also required to be used in the optimized configuration of the power transmission system, for the evaluation of the current energy saving effect by using the energy efficiency input/output ratio in the construction and subsequent maintenance stage. In case of the load loss in the air-conditioner power system, it is required to make the conditioning through the operation efficiency, make reasonable use of the heat medium optimization scheme in the control of the flow speed and the optimization design of the supply pipe, so as to finally achieve the expected demand for energy saving and environmental protection.

Finally, variable frequency technology is the optimal technical scheme for the energy saving effect in the overall system equipment improvement design. In the use of HVAC system, variable frequency technology demand is the key technology for regulating the temperature and energy output quantity. The variable frequency regulating can be used to control the heat energy transfer effect of HVAC system. Though the current regulating function cannot directly achieve the expected energy saving effect, it can minimize the possibility of energy consumption and the resource cost of the system operation. Usually, when HVAC system carries out the heat energy transmission according to the preset rated power, the relative load might decrease at any time. Supposing that HVAC system has had the rated power at this moment, it can realize the full-load operation. But in case of the heat energy transmission in such means, it would inevitably cause unfavorable situation of excessive energy consumption. So it is required to give proper stable temperature transmission and regulating to HVAC system through the variable frequency technology (Lu and Guo, 2010). Thus it can reach the optimal effect of controlling the output power, and with proper adjustment in case of the load change, it is possible to reach the expected heat energy transmission effect, and have the effect of energy saving and emission reduction. Therefore only after the combination with the actual load of the air conditioner, it is possible to realize the energy saving goal of HVAC system through the conversion of the wind flow and water flow. On one hand, for the variable air flow system, the end device of the air-conditioning system is used to realize the compensation mechanism of interior load, optimize and adjust the air supply quantity, to keep proper interior temperature, and compared with the fixed air flow system, the variable air flow system can save the energy by more than 50%, and has high energy control efficiency. On the other hand, for the variable water flow system, it mainly regulates the temperature by controlling the quantity, and saves more electricity by comparison with the fixed water flow system. Such technical indexes have been popularized and promoted with the technical development of the industrial inverter in China, and by optimizing and adjusting the air flow, water flow and main machine, it is possible to realize the matching operation with the air conditioner load, and achieve the optimal energy saving efficiency.
5. CONCLUSION

In summary, HVAC system has high energy consumption, which can be comparable to the total energy consumption of the building, and has very large threat on the effective control of the ecological energy (Zhang and Shi, 2011). Therefore, the all-new HVAC control system capable of saving the primary energy has become the major focus in the study of the air conditioners, and is also the final claim based on the key points for the energy saving and intensive development. Though multiple technologies are not perfect and cannot achieve 100% of energy utilization rate from the heat energy transmission efficiency, it can control the energy saving effect of HVAC system by comprehensive use of multiple technical indexes. The model optimization scheme of HVAC control system energy saving designed in this study is the comprehensive effect from the optimization design of the enclosure and the system equipment improvement design, achieving the expected energy saving and emission reduction goal. Though the reliable empirical study and verification has not been made on the physical building, it can still achieve certain energy saving effect from individual indexes of heat recycling technology, thermal media reduction, and inverter air conditioner technology. Besides, in the actual use, it is possible to evaluate the definition mode of the indexes in combination with the whole life cycle for the HVAC system energy saving model designed in this study, thus in the measurement dimension of the whole life cycle, the four evaluation indexes of \( S(u)=\{u_1,u_2,u_3,u_4\} \) are used for the comprehensive evaluation of the current energy saving effect, thus achieving the goal of defining the optimization direction. Different technological approaches are used to improve the operation environment of HVAC system, to achieve the expected energy saving and emission reduction effect.

REFERENCES

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