Model Research for Regional Architecture Planning of Distributed Comprehensive Energy Based on EnergyPlus Energy Consumption Simulation Engine

Yang Zhang, Haiyang Wang, Xiaojuan Li
Tianjin Chengjian University, Tianjin 300384, China

Abstract

Energy is an important support for human survival, and the efficient use of energy is directly related to the sustainable development of energy. In energy use, urban architecture is the primary energy consumption unit. To optimize the energy structure of urban buildings is of great practical significance to realize the sustainable development strategy of energy, and improve the quality of urban environment. At the present stage, China's urban planning is still in the stage of functional planning, failing to realize the active combination of concept of energy conservation and rational energy utilization and regional architecture planning. How to integrate energy planning concept into regional architecture planning has become an important research topic of urban planning. For that reason, this paper studies the regional architecture planning model of distributed comprehensive energy based on EnergyPlus energy consumption simulation engine so as to improve the planning of urban areas and achieve the sustainable development goals of urban energy.

Keywords: EnergyPlus, Energy Consumption Simulation, Distributed, Comprehensive Energy, Regional Architecture, Planning Model.

1. RESEARCH BACKGROUND

1.1 Research overview

Since the 21st century, extreme climate change has become a global concern of all countries around the world. The increasing emissions of greenhouse gases contribute to the melting of the two poles, and the rise in sea level also cause big change in the global climate. In this situation, how to reduce the emission of greenhouse gases, and achieve the energy conservation and emission reduction goal is an important measure for the benefit of all mankind. So the low-carbon concept emerges at the right moment. To develop the global economy with low-carbon concept, and realize low-carbon economy is the inevitable trend of social development in the future (Gu et al., 2017). China's urbanization construction process has been accelerating continuously, so as to make the cities expand constantly and the urban population grow constantly, which has also led to the rapid growth of urban energy consumption. The growth of greenhouse gas emissions in cities has reached a point that cannot be ignored. To comply with the trend of low-carbon economy, cities must take responsibility, and take corresponding measures to strengthen the integration efforts of cities so as to deal with global climate change and achieve the goal of low-carbon economic development as soon as possible. In the process of urban integration, buildings act as the main unit of energy consumption and greenhouse gas emissions, and it is very necessary to make rational planning of regional architecture. The planning of regional architecture should be guided by low-carbon concept. But how to apply low-carbon concept to regional architecture planning has become the most difficult problem for architectural planning (Li, 2017). The emergence of EnergyPlus energy consumption simulation engine provides new ideas for regional architecture planning, improves the science and rationality of regional architecture planning, and realizes the active combination of urban energy conservation and rational energy utilization and regional architecture planning.

1.2 Research purpose

The purpose of this paper is to raise the regional architecture planning level of cities, so as to make the regional planning more scientific and reasonable, improve and reduce the energy consumption of urban architecture, achieve the goals of urban low-carbon economic development, improve the energy utilization efficiency, and make
the energy sustainable development strategy implemented smoothly. For this purpose, in this paper, firstly, the EnergyPlus energy consumption simulation engine is briefly introduced, the distributed comprehensive energy based on EnergyPlus energy consumption simulation engine is proposed on this basis, and the characteristics of distributed comprehensive energy and the main factors influencing its efficient operation are discussed. Secondly, an in-depth study of regional architecture planning model for distributed comprehensive energy based on EnergyPlus energy consumption simulation engine is made, and the construction framework and construction principle of regional architecture planning model are clarified. In addition, this paper discusses the application of the distributed comprehensive energy based on EnergyPlus energy consumption simulation engine in the construction of regional architecture planning model, deeply analyzes the supply and demand situation of regional architecture energy model, and evaluates the built regional architecture energy model. This paper further discusses the index system and operation management mode of regional architecture energy model for distributed comprehensive energy based on EnergyPlus energy consumption simulation engine.

2. INTRODUCTION TO ENERGYPLUS ENERGY CONSUMPTION SIMULATION ENGINE

The EnergyPlus energy consumption simulation engine was developed jointly by Lawrence Berkeley National Laboratory and the United States Department of Energy. At present, it's a very popular free software, and structure of the software is modular. The EnergyPlus energy consumption simulation engine can carry on the deep economic analysis and the all-around building energy consumption simulation analysis of ventilation, refrigeration, lighting, heating and other energy consumption of buildings. There are two common user interfaces for the EnergyPlus energy consumption simulation engine, namely DesignBuilder and OpenStudio. As the simulation software was developed based on DOE-2 and BLAST software, it has all the advantages of the above two software. This also enables it to calculate the cooling and heating load based on the heating and ventilation air conditioning system and physical constitution of the building itself, and realize the very detailed data generation and output of building energy consumption (Chang et al., 2017). Figure 1 shows the schematic diagram of EnergyPlus module structure.

![Figure 1. Schematic Diagram of EnergyPlus Module Structure](image)

3. OVERVIEW OF DISTRIBUTED COMPREHENSIVE ENERGY BASED ON ENERGYPLUS ENERGY CONSUMPTION SIMULATION ENGINE

3.1 Characteristics of distributed comprehensive energy

The distributed comprehensive energy is a kind of energy supply method on the basis of the client, which can operate both synchronously and independently. It is a kind of system established with the goal of maximizing environmental benefit and resource benefit, which can meet the user's demand for energy, realize the optimal arrangement of resources. In addition, it is a new type of energy system developed using modular design and demand response design method, and it can be supplied in a decentralized manner (Peng et al., 2017). Compared with traditional separated end-use energy supply model, the distributed comprehensive energy has the following characteristics: Firstly, it can make the comprehensive utilization efficiency of energy greatly improved. Secondly, the environment of distributed comprehensive energy is friendly, which is mainly reflected in two aspects: On the one hand, it supplies power by being closing to the client, thus avoiding the establishment of large capacity long-distance transmission lines and effectively reducing electromagnetic pollution. On the other hand, its energy conversion technology is very advanced, with low gas emissions and low emission density. Thirdly, the distributed comprehensive energy is diversified in the form of energy supply and energy utilization. Fourthly, the energy supply of distributed comprehensive energy has high reliability, which can effectively make up for the deficiency in security and stability of power grid. Finally, the control management of distributed comprehensive energy has intelligent characteristics. It is based on the actual energy demand of the computer to optimize the energy supply and utilization, which may support remote network monitoring, and realize normal operation without any one on site (Li et al., 2016).
3.2 Distributed comprehensive energy based on EnergyPlus energy consumption simulation engine

The distributed comprehensive energy based on EnergyPlus energy consumption simulation engine has unparalleled advantages in regional architecture model, which is mainly reflected in six aspects: First, the distributed comprehensive energy based on EnergyPlus energy consumption simulation engine is a kind of large equipment, and compared with the small equipment, the large equipment may have high working efficiency, and low running cost and investment construction. Second, the distributed integrated energy of EnergyPlus energy consumption simulation engine is established on the basis of regional heating and cooling system, therefore, the distributed comprehensive energy can form a superposed advantage. Third, the distributed comprehensive energy based on EnergyPlus energy consumption simulation engine can meet the needs of smart grid scale development. Fourth, it can realize the synchronous development of urbanization and industrialization in China, accelerating the promotion process of large distributed energy system in China. Fifth, the distributed comprehensive energy based on EnergyPlus energy consumption simulation engine accelerates the development of natural gas in China and improves the efficiency of energy utilization. Sixth, it can realize diversified and efficient utilization of various energy resources (Liu et al., 2016).

3.3 Main influencing factors of efficient operation of distributed comprehensive energy

In the process of operation of the distributed comprehensive energy system based on EnergyPlus energy consumption simulation engine, the efficiency of its operation is mainly influenced by the following three factors, respectively energy consumption density, type and demand. Large energy consumption density may be beneficial to reduce the loss of energy in conveying process to some extent, and it can realize the integrated supply of four end-use energies: heating, air conditioning, hot water and steam. The system complexity may be increased accordingly by diversification of energy consumption type, but it can make the energy supply load smooth, and make the system and equipment utilization increase significantly. In addition, the diversification of energy consumption type can also guarantee the load stability of the system (Xue et al., 2016). The size of the demand is reflected in total load of the system and in the length of energy consumption time. These two aspects are important influencing factors to ensure the relative steady state of the system and maximize the use efficiency of the system.

4. STUDY ON REGIONAL ARCHITECTURE PLANNING MODEL OF DISTRIBUTED COMPREHENSIVE ENERGY BASED ON ENERGYPLUS ENERGY CONSUMPTION SIMULATION ENGINE

4.1 Framework of regional architecture energy planning model

The framework of regional architecture energy planning model based on EnergyPlus energy consumption simulation engine is to establish goals, carry out research on the policies, construction standards and cases of regional architecture, analyze the regional energy consumption demands, resource conditions and infrastructure according to the actual situation of regional architecture, and make clear the objectives and priorities of regional energy planning. Then, the regional architecture energy planning model is built, the energy demand and energy supply level of regional buildings are analyzed, and the scale, category, service scope and construction method of the energy supply system are established and selected. Finally, a diversified assessment and optimization of environmental and economic benefits for the constructed regional energy planning model is carried out (Tian et al., 2016). Figure 1 shows the schematic diagram of regional architecture energy planning model framework.
4.2 Principles of regional architecture energy planning model

Before the construction of the regional architecture energy planning model, the corresponding principles need to be followed. These principles are respectively principle of sustainable development, principle of adjusting measures to differing conditions, principle of balancing supply with demand and principle of guaranteeing the energy supply security (Xie, 2015). The establishment of regional architecture energy planning scheme needs to focus on environmental protection and governance objectives throughout the whole process, and the energy structure of the energy planning model needs to be optimized for vigorous promotion and application of green energy resources. In addition, during the construction of the regional architecture energy planning model, relevant characteristics of the planning area, architecture type, energy development and other aspects should be comprehensively considered so as to achieve the energy development strategy based on local conditions. At the same time, in the regional architecture energy model, the development conditions and development goals of the target area should be fully combined and the historical statistics should be queried so as to make in-depth analysis of factors influencing energy demand, clarify the quantitative relationship between these influencing factors and energy demand, and use the quantitative analysis method to analyze and adjust the balance of supply and demand and structural balance of energy. Finally, during construction of the regional energy planning model, it is necessary to ensure the security of energy in the supply process. There are two ways to solve the problem of energy supply security: one is to strengthen the construction of energy facilities and the other is to expand more diversified energy supply channels (Zhang et al., 2015).

4.3 Goals of the regional architecture energy planning model

The construction method of regional architecture energy planning model is not invariable, but should be set according to the specific situation of regional architecture. Setting goals for energy planning requires a comprehensive consideration of climate conditions, urban planning, resource environment, living habits and economic development of the area, as well as a combined consideration of different types of building functions and people's quality of life in the area (Li, 2015). The goals of the regional architecture energy planning mainly include the goals of being able to reflect the carbon emission efficiency and the regional architecture energy consumption, being able to reflect the absolute amount of carbon emission in the area, being able to reflect the regional energy structure, being able to reflect the regional users' degree of reduction in energy consumption, being able to reflect the regional green architecture standards and assessment, being able to reflect people's quality of life in the area, and being able to comprehensively reflect the environmental load ratio in the area (Wang et al., 2014).

4.4 Analysis of supply and demand of regional architecture energy planning model

This paper uses GIS technology to analyze the supply and demand of regional energy planning model, and uses the method of being from bottom to top to simulate the building energy consumption, and at the same time, uses the relevant parameters to construct the database of the sample. Firstly, it is necessary to embed the data in the model through GIS technology to obtain the required energy consumption requirements in the regional architecture. Then, the field situation of the area is investigated, and the potential of energy resources in the area is assessed. The two-step search method is used to analyze the energy supply and demand relationship in different situations, so as to identify the energy surplus or energy shortage in the area (Zhou, 2014). The GIS platform selects the corresponding model in the sample database according to the type of regional architecture, and the formula of the selected model is \[ C_{\text{tot}} = \sum_{i=1}^{n} K_i \sum_{j=1}^{m} C_{ij}. \] In this formula, the construction area of the \( i \)-th building in the target area is \( K_i \), the predictive parameter of \( j \) type building in the area is \( C_{ij} \), and the attribute unit matrix is expressed by \( I_{ij} \). If type of the \( i \)-th building in the area is \( j \), attribute unit matrix will be 1. If it is not \( j \) type, the attribute unit matrix will be 0. Total quantity of building in the area is expressed by \( N \), and total quantity of \( j \) type buildings in the area is expressed by \( M \) (Feng and Tian, 2014). In this paper, when the bottom-up method is used, both the sample statistical method and the simulation method may be used to assess the building energy consumption, and the spatial distribution of the buildings is combined with the energy consumption to predict the energy consumption in the area. The simulation method is used in this paper, and the EnergyPlus energy consumption simulation engine software is used. Its application idea is synchronous simulation, depending on the time step set by the user. The heat balance engine is used to calculate the load, and the load calculation results are transferred to the simulation module in the building system. The response of thermal and cooling system and power system is calculated by the variable time step, and then the calculation results are fed back to the load. If the calculation results cannot meet the requirements, the load calculation for the next time step should be calculated (Leng and Zhang, 2014). In the energy planning area, the regional energy is divided into two parts.
according to the supply and demand ratio, namely \( T_i = \frac{U_i}{\sum_{l \in (d_{ij} \leq d_o)} D_{L_i}} \) and \( K_i^F = \sum_{j \in (d_{ij} \geq d_o)} T_j \). In this formula, \( d_o \) is the service diameter range, supply and demand ratio of the energy supply point in \( d_o \) is \( T_j \), supply quantity of the energy supply point is \( U_j \), energy demand in the service diameter range of the energy supply point is \( D_{L_i} \), and the actual supply and demand ratio of energy in the energy demand area \( i \) is \( K_i^F \).

### 4.5 Evaluation on regional architecture energy planning model

The evaluation of regional architecture energy planning model is divided into evaluation on economic benefits and evaluation on carbon reduction benefits and potential of distributed comprehensive energy. The distributed comprehensive energy is designed to ensure that the energy demands of users in the area are met. Through investigation and evaluation analysis of the commercial interests from cooling, heating and power supply of regional buildings, the cost of investment and the cost recovery period of the system are calculated, the expected profit is predicted, and according to the cost of investment, cost recovery period, expected profit, carbon reduction volume and other calculation results of regional architecture energy planning scheme, an objective and scientific evaluation is carried out.

### 5. CONCLUSION

To sum up, in the research on regional architecture planning model of distributed integrated energy based on EnergyPlus energy consumption simulation engine, the planning of regional energy is directly related to the planning environment. Energy will have an impact on the site selection, morphology and scale of the city. But for distributed comprehensive energy, it is not only environmentally friendly, and it can also be diversified in energy utilization, with high utilization efficiency and stable energy supply. Because of these advantages, it plays an increasingly important role in the regional architecture planning. This is of great significance to promote the economic development of cities in China, and achieve the goals of energy conservation and emission reduction.

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