The Explore of the Implementation Path of Low-Carbon Smart Energy Systems in Zero-Carbon Parks

Zhang Jun[1], Qiao Biao[2*], Feng Chao[3], Qin Yipeng[2], Song Jialiang[1], Mu Lichun[1], Wang Lu[2]

[1] Guoshun Green Construction Technology Co., LTD, 251411 Jinan, China
[2] China Academy of Building Research, 100013 Beijing, China
[3] Shandong Guoshun Construction Group Co. LTD, 250306 Jinan, China

Abstract. With the development of economy and society, the energy demand increasing day by day. Building is one of the biggest energy consumption sectors, the park is composited of buildings. The build of zero carbon park is important to the decarbonizing in the building area. Based on the current status of the lack of smart energy system application in zero-carbon park, this paper mainly focuses on the implementation path of low-carbon smart energy systems in the parks, through the process of load prediction, energy demand analysis, system configuration, optimization and the development of energy management platform. A case study of zero -carbon park is analyzed to provide theory guide for future study.

1.Introduction

The park is the main component of the building complex and the basic unit of urban development, according to the data in the White Paper on Future Smart Parks [1], there are 90% of urban residents working and living in the parks and 80% of GDP being generated in the parks. As the main spatial carrier to undertake economic and social activities, the park is the space where energy, industry, buildings and other carbon emissions are centrally generated. According to the research data of 2021 [2], the industrial parks accounted for 69% of the total energy consumption and 31% of the total carbon emissions. Therefore, the construction of low-carbon or even zero-carbon parks is an important foundation for achieving the goal of carbon neutrality. 2021 October, the State Council issued the ‘Carbon Peak Action Program by 2030’ [3] proposed to build a dual-carbon ‘1 + N’ policy system. In the same year, the ‘Notice on Matters Related to Doing a Good Job in the Recycling Transformation of Parks in the 14th Five-Year Plan’ [4] required that a series of transformations should be carried out to promote the efficient use of resources in the parks and reduce carbon emissions by optimizing the spatial layout of industries and promoting energy saving and carbon reduction. The construction of low-carbon/zero-carbon parks is not only in line with the policy guidance, but also conducive to solving energy and environmental problems and promoting the realization of dual-carbon goals.

As a main part of the park's carbon emissions, the energy system is an important research direction for the park to achieve the zero-carbon goal and intelligent transformation. In 2001, the American Electric Power Research Institute proposed the concept of smart grid, and carried out research on smart buildings and energy networks, and after 2010, the building-integrated energy use scheme was formed [5]. In 2012, Henrik [6] proposed the concept of ‘smart energy system’ to realize the transformation of the energy system from a single model to an integrated model. Sun researches and develops an integrated energy management system for the Energy Internet [7]. In 2022, Cui researched a full-lifecycle integrated smart energy dispatching system from planning to operation and maintenance, which can assess the level of new energy consumption within the system [8]. The research on smart energy systems at home and abroad has made certain progress, and the framework, operation mode and application scenarios of energy systems are constantly developing. However, previous researches are mainly focused on the study of smart energy systems in buildings, with fewer research applications on energy systems in zero-carbon parks, and there are fewer case studies of actual projects and theoretical guidance on specific implementation methods. At the same time, the existing energy system in zero-carbon parks faces some problems related to the loads of different energy sources of cooling, heating, electricity, and gas, the problem of energy storage, and the instability of renewable energy utilization in the parks [9]. Therefore, this paper carries out research on the implementation path of low-carbon intelligent energy system in zero-carbon parks, taking a park in Shandong province as an example to explore the specific implementation method of low-carbon energy system and provide theoretical basis for subsequent similar projects.

* Corresponding author Qiao Biao: qiaobiao20@163.com

2.Multidimensional Indicator System for Zero Carbon Parks

In terms of zero-carbon park evaluation index research, in 2012, the Institute for Sustainable Communities (ISC) and the Guangdong Institute of Building Research jointly compiled the 'Low Carbon Park Development Guidelines', which formulated 4 categories evaluation index system of low carbon parks, such as energy utilization and greenhouse gas management, circular economy and environmental protection, et al. There are 23 secondary indicators [10], which provides important guidance for understanding the current situation of low-carbon parks, discovering existing problems and determining the future development direction. Paper [11], [12] and [13] take different industrial parks as examples to establish the evaluation system of low carbon parks and verify its effectiveness.

On the basis of data collection and case studies at home and abroad, this paper initially constructs the evaluation index system of the park mainly from the fields of low-carbon development, planning and design, architectural design, transportation system, water resources, energy, solid waste, environment, and operation and management, etc. The first-level indicator energy system is subdivided into four second-level indicators to assess the current situation of energy consumption and the improvement of the utilization rate of renewable energy in the park, taking into consideration the economy and carbon reduction effect of the indexes, and the specific indicators and their target reference values are shown in the table 1 below.

Table 1. Energy utilization indicators

First-level indicator	Second-level indicators	Target reference value
Energy system	Renewable energy use rate	≥15%
	Energy consumption per unit area	Unit area energy consumption ≤0.02kgce/m^2
	Percentage of renewable energy streetlights	≥80%
	Solar photovoltaic and solar thermal coverage of building roofs	≥50%

3.Implementation Path of Low Carbon Smart Energy System

The implementation path of the low-carbon smart energy system in the zero-carbon park is shown as the flow chart in Figure 1. First, load prediction is an important part of energy system research in the park, and the accuracy of the prediction of cooling, heating, electricity and gas loads in the park directly affects the design of the energy system, the allocation of the system capacity and the optimization. In this paper, TRNSYS software is used to simulate the buildings in the park, and the annual energy consumption of different energy systems is obtained by establishing models of different types of buildings in the park, and performing time-by-time dynamic simulation of cooling, heating, electricity and gas loads. Then, under the premise of obtaining the load in the park, various energy resource conditions and energy demand in the park are analyzed, and the matching relationship between energy supply and demand is analyzed, so as to formulate the design scheme of the energy system. On the basis of the energy system scheme, according to the composition and principles of the cooling, heating, electricity and gas systems, TRNSYS is used to establish a composite energy system model and carry out system simulation to determine the equipment capacity configuration. In order to optimize the operation strategy of the energy system and meet the monitoring and control requirements of the energy use in the park, the project develops a smart energy management cloud platform in conjunction with the actual use requirements. Based on the demand for data processing, analysis and sharing involved in the multi-energy complementary system in the smart energy, big data and cloud computing technologies are used to analyze and intelligently apply the data in the energy system through the cloud computing platform, so as to realize the decision-making scheduling.

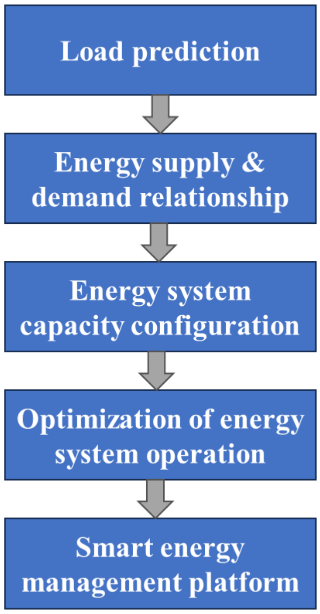

Figure 1. Flow chart of the Implementation Path of Low Carbon Smart Energy System

4.Case study analysis

In this paper, an industrial park in Shandong is taken as an example to study and analyze the technical solutions for the energy system of a zero-carbon park. The land area of the park is 114928 square meters, and the building type involves factory buildings, comprehensive buildings, dormitories, etc. Among them, the area of the comprehensive building is 15,233.48 square meters, with 12 stories and each floor height of 3.9 meters. TRNSYS is used to establish an energy model to calculate the dynamic load of the building throughout the year, and the model is shown in Figure 2.

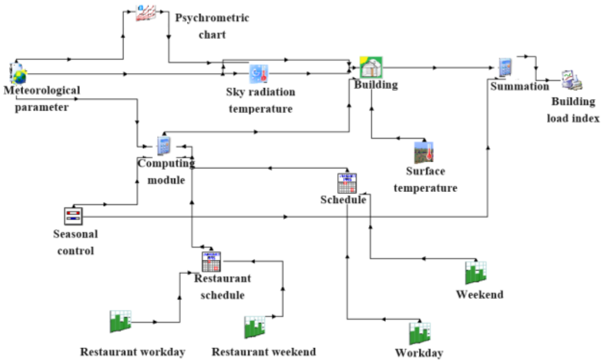

Figure 2. TRNSYS Simulation Model

Through calculation, the peak cooling load per unit area of the complex building is 63.17W/m^2, and the peak heating load is 19.24W/m^2. Using Hongye load calculation software for building load design calculation, the design load of cooling and heating is 53.58W/m^2 and 14.38W/m^2 respectively, and the actual cooling load of the building in summer is affected by the endothermic conditions and the usage habits, and this project is an office project, which needs to consider different types of functional usage requirements. The internal thermal conditions and the corresponding cooling load need to consider a certain margin, therefore, the design cooling load and heating load per unit area of the comprehensive building are 60W/m^2 and 25W/m^2 respectively.

According to the basic conditions of the project and the characteristics of energy use in the park, the project adopts the heat pump system to undertake the basic cooling and heating loads at the end of the building, and adopts the water storage tank for storing cooling and heating, and opens the release of energy during the peak period of electricity use, so as to fully improve the utilization rate of energy in the building and reduce the operating costs.

The TRNSYS model of air source heat pump and energy storage energy system are established, simulation calculations of 8760 hours throughout the year are carried out. Considering the variable frequency dynamic performance characteristics of the air source heat pump, according to the simulation results of this project, a larger storage capacity can reduce the capacity of the mainframe equipment and save operating costs, but considering the actual conditions of the project, the equipment needs to be set in the roof, and the storage tank volume should be reduced as much as possible, so according to the capacity configuration of 35.8% of the daily cumulative heating load demand, set 135m^3 storage tank. Tank.

The solar photovoltaic and storage batteries are set to make full use of renewable energy in the park, and an intelligent microgrid system is established based on the park's energy system as the energy foundation for the application of smart energy in near-zero energy buildings. By setting up photovoltaic power generation, power storage system, flexible load dissipation equipment, etc., the energy equipment is close to the demand side, making full use of new energy and renewable energy generation, and realizing the miniaturized system that matches local power generation and demand.

The energy system of this project is a composite energy system composed of air source heat pump, water storage energy, solar hot water and solar photovoltaic, and an energy management platform is set up to meet the demand for monitoring the energy consumption of the park. The data monitoring and intelligent transmission system monitors, collects and transmits real-time energy consumption data of the cooling and heating sources, endpoints, elevators, lighting and sockets. The monitoring and metering equipment at all levels are placed in the host of cooling and heating sources, water pumps, and each transmission pipeline, etc., to implement the monitoring of temperature, flow, pressure, power and other parameters, and after transmitting the monitoring data to the cloud platform, the cloud platform analyzes the operation of the system and formulates the corresponding operation and control strategies. After obtaining the accurate monitoring data of energy consumption of energy system, it evaluates the status and level of energy consumption of energy system and generates the alarm information when the energy system is abnormal through the statistics and analysis of energy consumption data of the building, combined with the cloud computing technology, big data energy consumption classification, energy consumption comparison, energy consumption early warning, energy management, and carbon emission accounting.

The scope of carbon emission calculation and statistical analysis of this project includes the carbon emissions of building HVAC, lighting, domestic hot water, and elevator systems in the park, and excludes facilities in industrial production, transportation, and other fields. In this paper, TRNSYS and IBE-E software are used to carry out simulation calculations to clarify the zero-carbon target of this project by calculating and analyzing the energy consumption and carbon emissions of the comprehensive buildings, leased housing and industrial plants in the park.

Without considering the case of external photovoltaic access to the building, the simulation of the building's HVAC system, lighting, domestic hot water, elevators and other energy consumption, to get the annual carbon emissions of the complex building is about 425 tons, the annual carbon emissions of rental housing apartments is 205 tons, the annual carbon emissions of the park's factory buildings is about 1,200 tons, and the park's total carbon emissions is about 1,822 tons. The project photovoltaic system annual average power generation is 2.377 million kWh, as well as the corresponding energy conversion factor, photovoltaic annual average carbon dioxide emission reduction of 1,862 tons of carbon dioxide, renewable energy generation of carbon emissions can meet its carbon emissions, to achieve the park's energy system of zero-carbon goals.

5.Conclusion

In summary, this paper takes the energy system of zero-carbon park as the research object and completes the research on the implementation path of intelligent energy system in zero-carbon park, which covers the whole process of designing system operation and monitoring of the park's resource demand program and makes up for the gaps in the research field; at the same time, taking the actual project as an example, it realizes the internal carbon neutrality of the park through the technical means of the intelligent energy system and renewable energy to achieve the goal of zero-carbon park, and it provides the guidance for the research on the implementation path of the park's energy system thereafter.

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