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Energy Procedia 00 (2014) 000–000

Energy Procedia

www.elsevier.com/locate/procedia

The 6th International Conference on Applied Energy – ICAE2014

Load Superposition and Shifting Method with Simulation tools for Energy Planning and the Case Analysis

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Abstract

Building energy consumption not only accounts for a large proportion of total energy consumption in a region, but also impacts building environment quality which affects people's living quality and work efficiency. So it has deep significance to get better building environment by less energy consumption and less emission reduction method. In this paper two demand side load superposition methods of regional energy system were proposed. The applicability of different methods was analyzed and the significance of load superposition was illustrated through an actual case study of the regional energy planning. It offers planners a feasible way to analyze the potential of load superposition.

Keywords：Energy planning, Load indicator, Energy consumption simulation, Load superposition

1. Introduction

The energy system consumption occupies a large proportion in a region, so regional energy planning inevitably plays an important role in energy conservation. If we consider the building load varied rate at the regional level and the load reducing from the stricter implementation of building codes as virtual resource, demand-side management is undoubtedly a kind of virtual resource.[1-2] Demand-side management consists of efficiency management using advanced technology and efficient equipment to save energy and load management mainly via load superposition and shifting. [3] Demand-side management requires no energy conversion, so energy-saving potential can be almost 100%. [4-5] But it is hardly fulfilled in practice at users level. However, Nikonowics pointed out that load superposition can be achieved at the regional level without changing of users' behaviors, so it has great application potential. [6] Load superposition and shifting also brings economic benefit. [7-8]. HVAC system occupies a larger proportion and has significantly loads shifting potential because of its strong volatility. This paper is aim to provide load superposition and shifting approach of HVAC system in regional energy system and offers planners a feasible way to analyze the potential of load superposition through a case study.

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2. Load superposition method

Traditional load superposition method can be expressed as: $Ep=\sum Lmi*Ai$ (i=1, 2, 3……n) (1)

Where n is the number of building types in superimposed area; Ep (W) is the total cooling/heating load in planning area; Lmi (W/㎡) is the cooling/heating load indicator of building type i; and Ai (㎡) is the air-conditioning area of building type i; Ep (W) is the peak value of Et.

As we know cooling/heating load indicator is always determined by code or designers' experience. Compared with the real-time load, one side it has a large amplification effect, the other side it can't reflect the hourly load and building thermal delay effect. So in order to solve those problems, the following methods are proposed.

2.1. Indicator—simultaneity factor method

Indicator, which is formulated in the national or provincial building code, refers to the cooling and heating load of different building types. Simultaneity factor refers to the ratio of the rated load of a system in a building at the same time. Equations (2) Planning area hourly load superposition equation and (3) Planning area peak load equation are used in this method.

$Et=\sum_{i=1}^{n} \zeta it * Li * Ai$, t=1,2,3······24 (2) $Ep=Max(Et，t=1、2、3······24)$ (3)

Where n is the number of building types in superimposed area; Et (W) is the superimposed cooling/heating load in superimposed area at hour t in one day; ζit is the simultaneity factor of building type i at hour t; Li (W/㎡) is the cooling/heating load indicator of building type i; Ai (㎡) is the air-conditioning area of building type i; and Ep (W) is the peak value of Et.

2.2. Simulation method

Take the advantages of simulation software to obtain data and analyze and solve problems. Actually, simulation method uses the given conditions and obtained data of the above method and site survey results as reference and constraints. Equations (4) Planning area hourly load superposition equation and (5) Planning area peak load equation are used in simulation method.

$Et=\sum_{i=1}^{n} Lit * Ai$, t=1,2,3······8760 (4)

$Ep=Max(Et，t=1、2、3······8760)$ (5)

Where n is the number of building types in superimposed area; Et (W) is the superimposed cooling/heating load in the area at hour t in one year; Lit (W/㎡) is the cooling/heating load indicator of building type i; Ai (㎡) is the air-conditioning area of building type i; and Ep (W) is the peak value of Et.

Fore in indicator—simultaneity factor method, the data is obtained based on unified building code. It is the easiest and the most feasible method. However, this method is not targeted on the planning area specifically, so the results are likely to deviate from the actual situation. While simulation method is

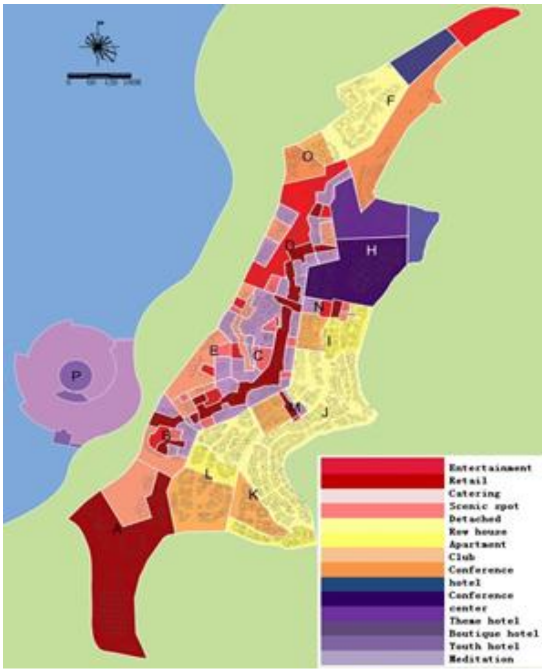

Fig.1 Distribution of different building types

well operational, professional and adjustable, but in this method high professional and technical persons are needed and it will take longer time.

3. Case study

It is a tourist resort by Taihu Lake. The planning area can be divided into 15 zones A-P by superior planner and contains 14 kinds of architectural types which are given numbers as 1.Entertainment, 2.Retail, 3.Catering, 4.Scenic spot, 5.Detached, 6.Row house, 7.Apartment, 8.Club, 9.Conference hotel, 10.Conference center, 11.Theme hotel, 12.Boutique hotel, 13Youth hotel, 14Meditation. The specific distribution and areas are shown in Figure 1 and Figure 4, 5.

EnergyPlus is utilized to simulate building energy consumption. The model is established in full accordance with the shape and size of architectural building drawings, and the materials of roofs, walls and windows in the model are the true reflection of the actual construction materials. In addition heat transfer coefficient of roof, wall and window, transmittance of windows, air tightness of external doors, etc. are obtained by practical testing in established room. All models are built close to reality as far as possible, and can authentically reflect cooling load and energy consumption level of practical buildings.

3.1. Load calculation based on indicator—simultaneity factor Method

In this paper indicator refer to "Cooling Load Designing Specifications of Domestic Buildings" and "Estimated Heating Indicator of Civil Buildings", see figure 2. Cooling and heating load based on indicator is relatively larger, but the surplus value can't be measured exactly. In this case we can make a clear comparison. Figure 3 also shows simulated peak cooling and heating load. It is obvious the indicators are 1.2~2.1 times as much as simulated data.

Combined with the "Public Building Energy Efficiency Design Standards" GB50189-2005 and practical operating situation, air-conditioning system simultaneity factors of different functional zones can be obtained as Figure 3.

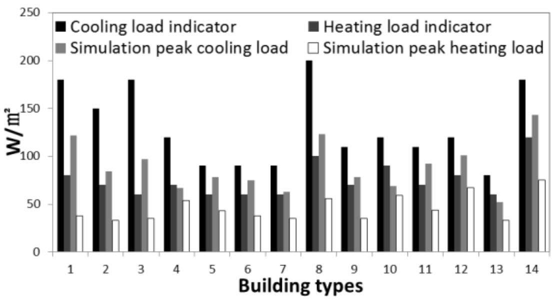

Fig.2 Cooling/heating load summary of all building types

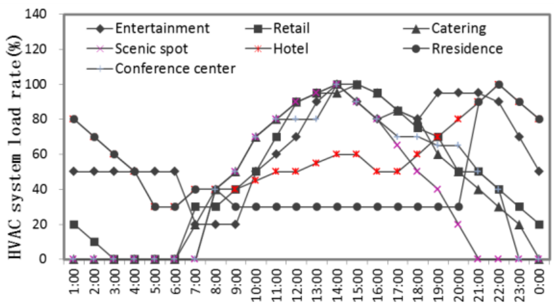

Fig.3 Simultaneity factors of different functional zones

Based on indicator-simultaneity factor method through multiplying by cooling load indicator and simultaneity factor appears the peak load 103.4W/㎡ at 14:00. Multiplying by simulated cooling load and simultaneity factor, appears the peak load 68.9W/㎡ at 22:00.

HVAC system equipment is selected based on cooling load, in this way load calculation is in accordance with cooling load as well. We can draw the following conclusion: 1. The values selected based on indicator is 1.5 times amplified; 2. Simulation results can reflect not only cooling load but also the building envelope thermal delay effect, namely thermal inertia.

3.2. Load superposition based on simulation method

Simulated and total peak cooling and heating load of different functional buildings is shown in Figure 4. The sums of all building types' cooling and heating load are 25.0MW and 13.3MW. Total and superposed peak cooling and heating load of single zones is shown in Figure 5. Total cooling and heating load are 20.7MW and 10.8MW. Compared with the result in Figure 4, total cooling and heating load are declined by 17.1% and 19.2% respectively. Total and superposed peak cooling and heating load of multiple zones is shown in Figure 6. The cooling and heating load are 17.4MW and 9.7MW respectively. Cooling and heating load are reduced by 30.5% and 27.2% in comparison with Figure 4.

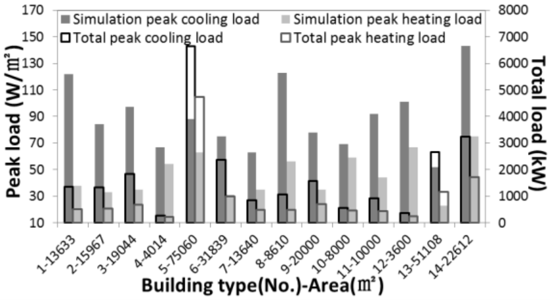

Fig.4 Simulated and total peak cooling/heating load of different functional buildings

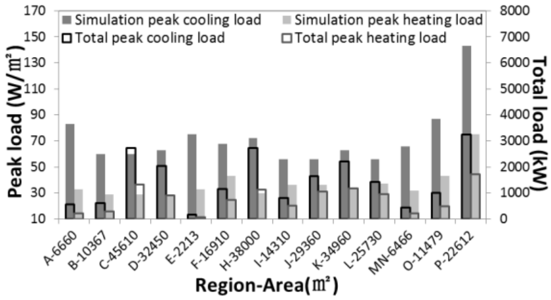

Fig.5 Total and superposed peak cooling/heating load of single zones

Subdivision approach in Figure 4 is within single zones. The buildings in every zone are not diverse. While the subdivision approach in Figure 6 is based on 3 factors: 1. Location proximity principle, namely adjacent buildings are divided into the same zone. 2. Moderate size principle. We take both load superposition effect and outdoor pipe network and energy station cost into account and seek a balance point. 3. Diversification principle. The more diversified building types are contained in the same region, the more ideal is the load superposition effect, and vice versa.

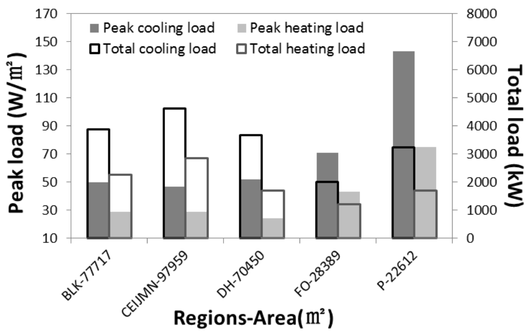

Fig.6 Total and superposed peak cooling/ heating load of multiple zones

4. Conclusion

Through the case study, we can conclude that demand-side cooling load superposition of diverse buildings is significant different by using indicator and simulation method respectively. Amplification effect of indicator method is particularly obvious and it can't reflect building thermal delay effect. As long as the time and technology are guaranteed, it is recommended to utilize simulation method to obtain more reliable and accurate demand-side load.

Aiming at subdivision of planning area we put forward three principles and they should be observed in planning: 1. Location proximity principle, avoiding jumping subdivision; 2. Moderate size principle, balancing load superposition effect and initial investment; 3. Diversification principle. The more diversified building types are contained in the same region, the more ideal is the load superposition effect.

The load superposition and shifting method can be widely applied. To the area, in which the buildings have small volume, large quantity and are intensive, such as tourist resort, the objective is large numbers of buildings in subdivided zones. To the single building with large volume, such as large public building, the objective can be different functional parts within itself or the different functional buildings nearby.

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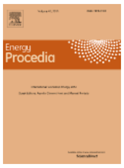

Biography

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