A Review and Prospect of Development of District Energy Modeling

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Abstract. The article aims to review the main research field of district energy modeling. It summarizes achievements in building area, industrial area and urban area. The development of district energy modeling with application of energy internet and big data technology is analyzed. The article also makes prospect for future research.

1. Introduction

With the increasing energy demand owing to improvement of people’s living standards and development of industry, and the growing contradiction between energy extraction and environmental protection, energy issues have drawn great attention in industry and academia in the last few years. To improve the utility of energy while protecting resources and being environmentally friendly, is a major challenge faced by the world. To solve the energy problem, we need to make scientific and rational energy planning, which requires modeling of district energy and comprehensive analysis. Therefore, researchers have focused on the studies of district energy modeling and analysis, which promotes improvement in energy utility. Meanwhile, concepts such as the energy Internet [1] and the integrated energy system [2] emerged at the historic moment. With the popularity of “Internet + smart energy”, which the government promotes, energy reform in China is deepened. The rapid developing big data science encourages many researchers to apply the technology in the modelling of district energy, creating lots of academic sparks. The development of these theories and technologies provides a new perspective to study district energy models, and promotes academic cross in many disciplinary fields. This paper studies modeling of district energy. Firstly, existing modeling methods of district energy and corresponding software are analyzed and summarized. Secondly, it focuses on the energy Internet. A review on the application of energy Internet theories and technologies in district energy modeling is conducted. Thirdly, it discusses the studies in which big data technology is applied to district energy modeling. Lastly, the paper prospects the development of district energy modeling from the three aspects.

2. Review of regional energy model analysis

2.1. Research status of regional energy model analysis

Both qualitative and quantitative methods have their own advantages and disadvantages in energy analysis. The qualitative methods are usually limited by the strong subjectivity and poor repeatability. When applying quantitative methods, there might be great gaps in theoretical and practical system. The researches on district energy models make energy system simulation more objective and credible. Achievements in district energy modeling have been made. Researchers use different research
methods to tackle with different types of areas, mainly including: building areas, industrial areas and urban areas. The research status of the three types is analyzed as followed.

2.1.1. Building Areas. Today, we are faced with global environmental and energy crisis. A great number of residential zones with large area are consuming huge amount of energy every day. Popularizing energy conservation in these areas will greatly relieve the pressure caused by energy crisis. The research on the field is characterized by modeling energy-saving systems based on building technology. District energy saving status is analyzed and summarized using the model, and therefore it provides strategies for development in the future.

In "Building Up A Computer Model of Housing Energy-saving Design" [3], Zheng Zhi, Liu Wei et al simulated energy saving of regional buildings with computer technology. The model includes architectural model and the environmental model. The architectural model is composed of modules of architectural structure, architectural equipment, and human body sensing. The environmental model is composed of geographic module, climate module and periodic module. Beijing Wangfujing commercial area is taken as an example for modeling and analysis.

Liu Di, Wu Junyong et al. introduced the concept of integrated energy system (IES) in "Planning Method of Integrated Energy System Based on Kriging Model" [4]. IES is a integration system of energy production, supply and marketing, in which processes such as energy production, transmission, conversion, storage and consumption are coordinated and optimized during planning, construction and operation. The authors simplified the original optimal IES model using the Kriging model (the Kriging model is an interpolation method for predicting spatial data by calculating the weighted average of given points), to optimize process, improve accuracy and shorten calculation time. In the paper, modules of cooling, heating and power were set up for a building, and analysis based on the model was conducted. It provides a energy-saving operation optimization diagram of the building in different seasons.

HOMER, researched and developed by the National Renewable Energy Laboratory (NREL), has been widely used in abroad studies in the last few years. The advantage of HOMER lies in its strong adaptability. It is applicable to various energy regions of all sizes, and its characteristics of hybrid energy model allow it to perform better comprehensive analysis than traditional models. HOMER has been widely used in energy planning and design optimization, especially in small villages, communities and housings. Its simulated optimal solution provides strong information support and suggestions in technique and development plan. Dalton G J, Lockington D A, Baldock T E [5] studied a large-scale sightseeing hotel on Queens Island Australia, which is in subtropical coastal area. Energy modeling and design optimization are conducted. The results shows similar cost of net present value when compared with that of HOMER model. In reference [6], it plans to, using HOMER, build a zero energy home that does not consume any fossil energy. The paper takes several housings as research object, building a unique energy-saving system. Consuming renewable energy is enough to maintain the normal operation of daily life in the system.

2.1.2. Industrial Areas. With huge consumption in industrial areas, much research on district energy conservation in industrial areas has been done around the world. Equilibrium model is widely used in industrial energy conservation, mainly including material balance model, energy supply and demand equilibrium model and energy equilibrium model. The models are built based on equilibrium equations with physical significance. Based on analysis of Baosteel Group's production data in 1998, and technical summaries of various production processes, Chen Guang [7] built a optimization energy model of Baosteel. The model adopts equilibrium equation of energy supply and demand, energy equilibrium equation and material balance equation.

In the Study on Architecture of Energy Model of Iron and Steel Enterprise [8], Zhao Fei, Zhu Jun, Li Li, et al, taking an iron and steel enterprise as object, proposed a multi-view integrated architecture of energy modeling, MIEEMF. MIEEMF focuses on the major processes in traditional iron and steel
industry, which is coking, sintering, iron making and steel making. It is a multi-view and multi-dimensional energy model of iron and steel enterprises.

2.1.3. Urban Areas. With the advancement of technology and the development of human society, energy demand increases in urban areas where human beings gather. However, the increasing urban energy demand brings a heavy burden on environment and resources. In this context, the researchers proposed a distributed energy system that integrates the supply and demand of energy including cooling, heating and power, to improve energy efficiency and promote reform of urban energy.

In Influence of Urban Spatial Structure on Energy and Environmental Performance of Regional Distributed Energy System [9], Ren Hongbo built an energy analysis model for urban areas, which is comprise of physical module of energy system and evaluation module of energy conservation and emission reduction. The urban area in Shanghai was analyzed in the paper. The household energy consumption obtained using the model was compared with previous research results, and suggestions for energy planning in Shanghai were given.

In Factors Affecting Chinese Urban Household Energy Consumption and Spatial Differences Based on Static Panel Data Modelling for Eight Regions [10], Liu Manzhi and Ren Xianxian analyzed household energy consumption in urban areas in China, using panel data model. The paper divides the country into eight regions, and impacts of disposable income, budget, prices and policies are taken into consideration in the model. It shows that, from 2000 to 2013, there is a long-term equilibrium relationship between the total urban household energy consumption and the affective factors in the model. Energy price has the greatest impact on urban household energy consumption, followed by actual consumption expenditure, and policies have least impact.

2.2. District Energy Modeling and Energy Internet
The idea of building energy Internet was first proposed in 2004 in a paper published on The Economist, Building the Energy Internet. It introduced Internet to traditional power system, and based on the features of self-healing and plug-and-play, they built a intelligent digital power system with higher response rate and self-healing ability. Therefore, power supply failures are reduced and the impact is weakened [11].

The regional integrated energy system is the embodiment of energy Internet in energy synergy. In Review of Steady-state Analysis of Typical Regional Integrated Energy System under the Background of Energy Internet [12], Wang Weiliang, Wang Dan, Jia Hongjie, et al partitioned the integrated energy system into users' level, regional level and district level and built a energy model. In the partitioning energy model, typical energy systems such as power, natural gas, and heat were studied. The study applies energy hubs to modeling of steady-state issues of integrated energy systems, and problems of demand management, planning and optimization in the system were discussed. A detailed analysis is made based on case study. The paper hopes to provide research ideas of development and collaborative utilization of multi-energy to realize energy Internet.

Tian Songfeng, Tian Peng, Liu Danna, et al, in Application research and case analysis of regional energy internet in urban [13], designed a regional energy management model using a network mapping platform and various computer programming software. The model provides monitoring support in cooling, thermal and power load and the flow direction in real time, and helps to make rational allocation and planing in supply-demand of the energy station. The model facilitates data query and sharing for relevant departments.

2.3. District Energy Modeling and Big Data
Nowadays the big data is a fast developing industry, with the expansion application it can be seen in various fields. Applying big data technology to the energy industry is to integrate energy production and consumption with technological innovation. The development of energy industry is expected to be accelerated in use of the technology and innovative business models are to emerge.
Jiang Xiufang, Zhang Weichang and Chen Hongwei analyzed the advantages and feasibility of applying big data to energy industry in Big Data and Development of Energy and Electricity Industry [14]. They put forward advises on practical implementation, for example, the incorporation of smart meter, customer service in new form and new energy; intelligent maintenance. In case study, cases of Zhejiang province and Shandong province are analyzed. Findings show that the introduction of big data technology in energy model effectively improves energy utilization and model simulating rate.

3. Research Prospects
According to the existing studies of district energy modeling, and the development of energy Internet and big data technology, the paper discusses prospects for future research.

(1) In order to alleviate the pressure on energy resources, exploitation and utilization technologies of renewable energy must be further developed. Therefore, we expect to see more engagement of renewable energy sources in energy models in future research. Working out sound energy plannings, making best use of district energy modeling, could help the marketization of renewable energy.

(2) The development of regional energy Internet technology provides district energy modeling better platforms and materials. On the other hand, research results and energy plannings generated from district energy modeling will further promote the development of energy Internet.

(3) The vigorous development of big data technology makes better modeling of district energy possible, which will greatly improve the accuracy of results and the feasibility of planning. The combination of district energy modeling and big data is a major research area in future.

4. Conclusion
Today, increasing attention is paid to the research on district energy modeling. The models have developed, from top-down and bottom-up models, to a hybrid energy model, which enables more systematic and comprehensive analysis of district energy. Modeling in building areas, industrial areas and urban areas will be more practical with the application of energy Internet and big data technology. The planning made in use of modeling will better guide the construction and therefore improve people's lives in the future.

In this paper, the studies on district energy modeling at home and abroad is reviewed according to different areas. It also prospects the development in future. The study aims to provide research ideas on district energy modeling.

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