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AN OPTIMIZATION FOR DISTRIBUTED ENERGY SYSTEM INTEGRATED WITH DISTRICT ELECTRICITY NETWORK

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ABSTRACT

This paper develops a mixed integer linear programming model for optimal design and hourly operation schedules of distributed energy system integrated with electricity network. In this model, the real time control of the electricity interchange among end-users was determined. As an illustrative example, the model was used to a case study consisting of three types of buildings, including hotels, offices and residential buildings, in Dalian, China. Through the optimization, configuration design (capacities) and operational results (energy supply control) are obtained. The results show that with the application of electricity network, excess electricity produced by hotels and offices were transferred to residential buildings in mid-season day. In winter day, all the electricity demand can be supplied by a combination of generated by PGU and interchanged from other buildings in the region and there is no need to purchase from utility.

Keywords: distributed energy system, energy exchange, electricity network, real time control.

NONMENCLATURE

Abbreviations	
DES	Distributed energy system
PGU	power generation unit

Symbols	
COP	Coefficient of performance
C	Cooling demand
H	Heat consumption
E	electricity
P	the capacity of generated unit
cap	capital cost
b	boiler
l	The types of building
m	month
h	hour
d	day
in	input
out	output

1. INTRODUCTION

Recently, Distributed energy system (DES) has been widely used in cities because of its high energy generation efficiency. And the growth of energy demands and environmental concerns have been attracting significant attention [1-3].

DES integrated with energy network which allows for energy sharing between various users has been investigated. Varasteh et al. [13] addressed the network expansion planning of an active Combined Cooling, Heating and Power (CCHP) systems with their heating and cooling network. Kang et al [14] designed a DES with a district cooling system with the real site energy demands. Casisi et al. [10] developed a MILP model of a distributed cogeneration system with a district heating network and heat losses.

According to the above discussion, many studies have focus on the optimization of the DES integrating with heating and cooling network, however, there is still a lack of studies paying close attention on electricity network. This paper presents a multi-objective MILP model that integrates a distributed energy system with a decentralized district electricity network. The model can determine the DES configuration and respective capacities, and optimal operation of district electricity network to satisfy time-varying use demands. The model was used for multi-objective formulation, with two objectives of minimization of total cost and pollutant emissions.

2. MATHEMATICAL MODEL

As an illustrative example, the model is applied to three types of buildings (hotel, office and residential building) located in Dalian, China. In this study, three typical days per year, namely winter, summer and mid-season days, were introduced regarding to hourly variations in energy demands.

Electricity network was added to DES of this region. Meanwhile, the optimal operating schedule was obtained through real-time control of actual electricity demand, which implies that each building can exchange electricity with other buildings through intelligent control.

2.1 *Power generate unit*

P_{cap} is the capacity of power generate unit (PGU), and *m, d, h* means month, day and hour respectively. E_{pgu} is the electricity generated by PGU. *H* is the heat recovered from PGU andμ_{rec} is the recovery factor.

$$P_{cap} \cdot 25\% \le E_{pgu,m,d,h} \le P_{cap} \quad (1)$$

$$H_{pgu,m,d,h} = E_{pgu,m,d,h} \mu_{rec} \quad (2)$$

2.2 Electrical chiller

The cooling generated from electrical chiller (C_{ec}) should not exceed its rated capacity (C_{cap}). The electricity (E_{ec}) can be illustrated as shown in Eq (3)

$$C_{ec,m,d,h} \le C_{cap} \quad (3)$$

$$E_{ec,m,d,h} = C_{ec,m,d,h} / COP_{ec} \quad (4)$$

2.3 Gas boiler

The heat output of a boiler (H_b) to the rated capacity (H_{cap}) is constrained in Eq (5):

$$H_{b,m,d,h} \le H_{cap} \quad (5)$$

2.4 Electricity balance

The energy balance of electricity is represented in Eq (6), in which the left part is the electricity input flows from PGU, the utility grid and the exchange electricity from other buildings, the right part refers to the output flows including electrical chiller for cooling demand and the interchange electricity transported to other buildings.

$$\sum_l E_{pgu,m,d,h,l} + E_{pur,i,m,d,h} + E_{in,i,m,d,h} = E_{demand,i,m,d,h} + C_{demand,i,m,d,h} + E_{out,i,m,d,h} \quad (6)$$

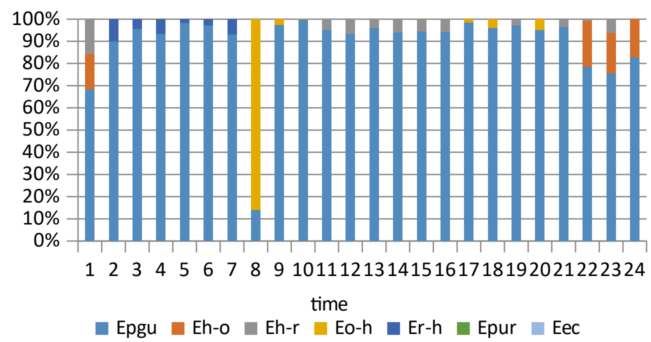
2.5 Heat balance

As shown in Eq (7), heating flows in contains feed flows of all producers. On the other hand, heating flows out include heating demand.

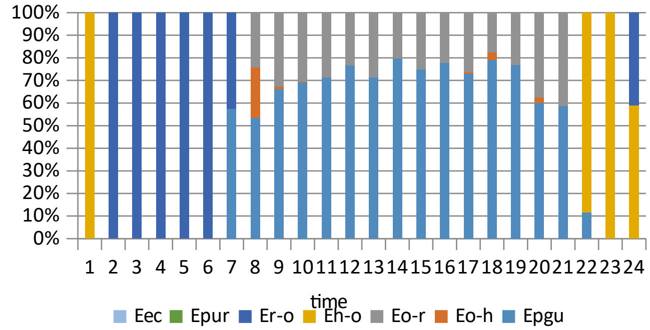
$$\sum_l H_{pgu,m,d,h,l} + H_{b,i,m,d,h} = Hdemand_{i,m,d,h} \quad (7)$$

3. RESULTS AND DISCUSSION

The capacity of PGU candidates are [230, 470, 633, 800]. According to the optimization results, the capacity of 633 kW was installed in hotel, 800 kW was allocated in office, and 470 kW was installed in residential buildings. It is also important to study the electricity interchange between each building through the distribution grid. The hourly optimal interchange between the three typical buildings in winter day was presented in Fig.1. It reflected the cooperative relationship of end-users within the electricity network. For example, the value of $E_{h\text{-}o}$ implies the electricity supply from hotel to office, whereas the $E_{o\text{-}h}$ is the deficit part that is from office to hotel.



(a)



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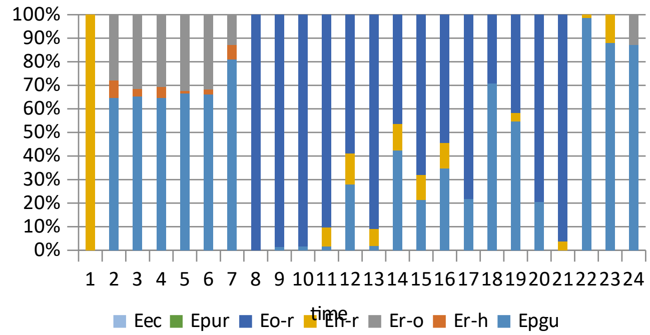
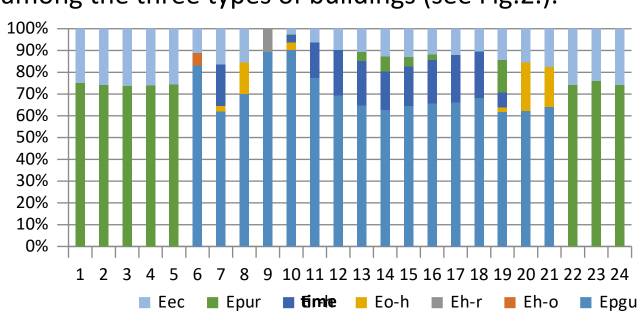


(c)

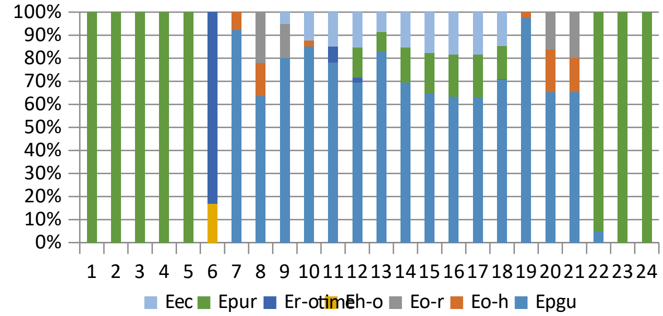
Fig. 1. Hourly electricity balance of hotels (a), offices (b) and residential buildings (c) in typical winter days.

From Fig 1, in hotels, electricity demand is almost evenly served by electricity generated by the PGU for self-use in winter day. For offices, during the night time, PGU is out of work, the electricity demands are also supplemented from residential buildings and hotels. While for residential buildings, the installed capacity of PGU cannot satisfy the higher demand in daytime and the majority of the electricity is also transferred from residential buildings. It can be observably shown in Fig.1, all the demand can be generated by PGU and exchanged from other buildings in the region and there is no need to purchase from utility, which can obtain higher system efficiency.

In the following, a typical day representing summer is selected to show the hourly electricity supply strategy among the three types of buildings (see Fig.2.).



(a)



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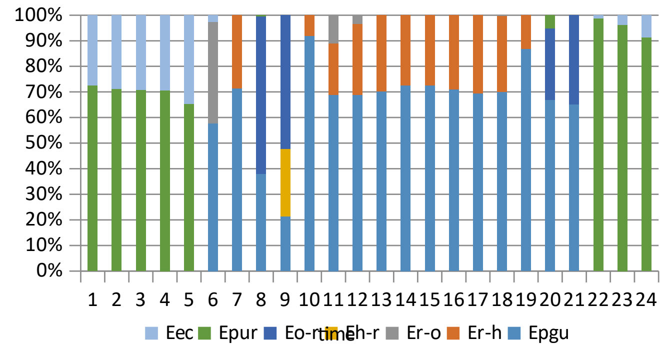
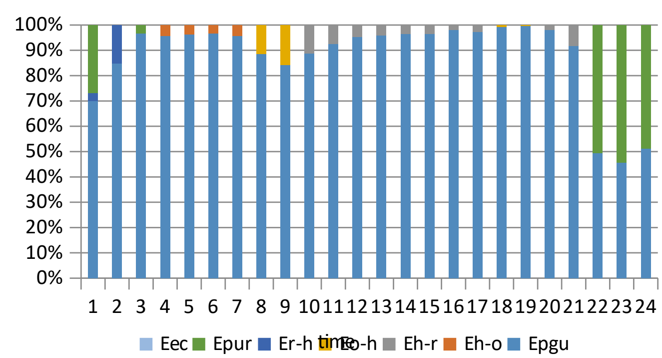


(c)

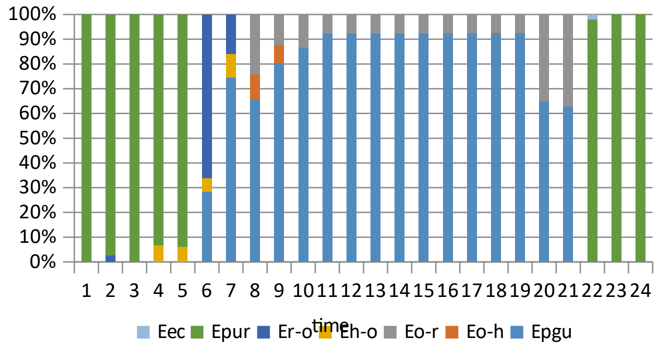
Fig.2 Hourly electricity balance of hotels (a), offices (b) and residential buildings (c) in typical summer day.

It can be concluded from the three types of typical buildings in Fig.2 that during night time, most of the electricity demand were purchased from utility and partly used for electricity chillers. During daytime, majority of electricity demand in hotels were supplied by a combination of interchanged from residential building and purchased from utility. Therefore for residential buildings, especially from 11 am to 18 pm, over 20% of its generated electricity was transferred to hotels due to its lower electricity demand in this time periods.

Fig.3. shows the electricity balancing results for typical buildings in mid-season days.



(a)



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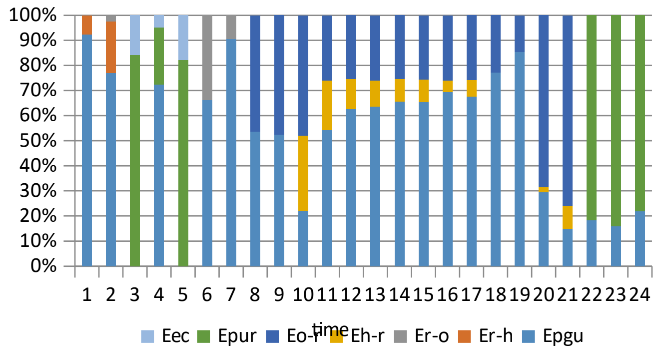

(c)

Fig.3 Hourly electricity balance of hotels (a), offices (b) and residential buildings (c) in typical mid-season day.

For the hotels, PGU almost operated the entire day, and the result was the same as in winter day. During night time for offices, most of the electricity was purchased from utility, which was the same as in summer day. However, for residential buildings in mid-season day, the electricity transferred direction was different from other two typical days. Except for electricity generated by PGU, most of the interchanged electricity demand is supplied by a combination of exchanged from hotels and offices. One reason for this is that the total installed capacity of PGU for residential buildings is decreased.

Looking into above figures, it can be concluded that the load rate of the PGU in hotel and office are improved with electricity network and the generated units often operated at full loads, which is higher than the hourly demand. This is because of the application of the electricity network, the surplus electricity can distribute to the residential buildings.

4. CONCLUSIONS

In this paper, a MILP model has been developed for the optimization of hourly operation schedules of distributed energy system integrated with electricity network. The model was used in a region containing hotel, office and residential building in Dalian, China. According to the discussion and results, the conclusion can be deduced as follows:

(1) In winter day, all the demand can be generated by PGU and exchanged from other buildings in the region and there is no need to purchase from utility.

(2) In summer day, during night time, most of the electricity demand was purchased from utility in all three types of typical buildings.

(3) In mid-season day, the interchanged direction of majority of electricity demand is from hotels and offices to residential buildings, which is different from other two typical days.

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REFERENCE

[1] Ackermann, T; Andersson, G; Soder, L. Distributed generation: a definition. Electr Power Syst Res 2001;57(3): 195-204.

[2] Yang, Y.; Zhang, S.J.; Xiao, Y.H. Optimal design of distributed energy resource systems coupled with energy distribution networks. Energy 85 (2015) 433-448.

[3] Wu, Q.; Ren, H.B.; Gao, W.J.; Ren,J.X. Multi-objective optimization of a distributed energy network integrated with heating interchange. Energy 109 (2016) 353-364.

[4] Varasteh,F., Nazar, M.S., Heidari.A, Shafie-khah.M, Catalao, J.P.S. Distributed energy resource and network expansion planning of a CCHP based active microgrid considering demand response programs. Energy 2019 (172) 79-105.

[5] Kang,J., Wang, S.W., Yan, C.C. A new distributed energy system configuration for cooling dominated districts and the performance assessment based on real site measurements. Renewable Energy 2019 (131) 390-403.

[6] Casisi M, Pinamonti P, Reini M. Optimal lay-out and operation of combined heat & power (CHP) distributed generation systems. Energy 2009: 34: 2175-83.