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A Day-ahead Optimal Economic Dispatch Schedule for Multi Energy Interconnected Region

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Abstract

The energy supply center of the multi energy interconnected region is an energy station, which contains many types of energy supply equipment to match the cold, heating and power loads. This paper proposed a day-ahead optimal economic dispatch model for multi energy interconnected region based on centralized and interconnected energy exchange framework. In the model, the constraints of regional network topology are taken into account. The model is solved by the interior point method in this paper. A case study shows that by performing the schedule made by the dispatch model, the daily operation cost of the multi energy interconnected region decreasing remarkably, thus demonstrates the effectiveness of the proposed economic dispatch schedule.

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Keywords: Multi energy interconnected region; energy station; optimal economic dispatch; combined cooling, heat and power (CCHP); interior point method

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1. Introduction

Multi energy interconnected region contains four kinds of energy forms: cold, heat, electricity and gas, integrates all kinds of energy supply equipment in the regional energy station and makes a unified operation schedule by information technology and internet of things to achieve the goals of energy supply optimization[1].

CCHP(Combined Cooling Heating and Power)system as a typical representative of multi energy interconnected region [2] ， has become an important means to improve energy utilization efficiency, solve energy shortage and environmental pollution issues by its high energy consumption efficiency, flexible and reliable energy supply mode[3].

In our study, a day-ahead optimal economic dispatch model for multi energy interconnected region is established based on centralized and interconnected energy exchange framework and solved by the interior point method with Hessian matrix iteration. Our contributions in this paper include the following.

(1) Constraints of regional network topology are taken into account in the proposed model, the objective function also considered network losses, the model is closer to realistic situations compared to traditional models.

(2) Proposed dispatch method performs better than other traditional control methods of the energy supply equipment, which is shown in the simulation results that the daily operation cost of the multi energy interconnected region decreasing remarkably compared with traditional control methods.

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2. Optimal economic dispatch model for multi energy interconnected region

Multi energy interconnected region contains many types of energy supply equipment to match the cold, heating and power loads. To achieve the goal of efficient allocation of cooling, heat, electricity and gas, optimal economic dispatch schedule must be made for energy supply and storage equipment in the energy station to adjust the operation mode and output.

In this study, after the modeling of energy supply and storage devices, economic optimization objective function of the multi energy interconnected region is established considering the influences of TOU price. The optimal operation schedule is obtained by solving the dispatch model.

Assumptions of the model are as follows:

(1)Output of energy supply and storage equipment is continuous.

(2)Equipment failure does not occur during operation periods.

2.1. Optimization Objective

The optimization objective is the minimum of daily operation cost of the multi energy interconnected region, including fuel costs, power purchase costs, equipment maintenance costs and network losses costs, as in (1)

$$\min price = \min(pri_{fuel} + pri_{Grid} + pri_{loss}) \tag{1}$$

The fuel costs of micro turbine systems and gas boiler are shown in (2)

$$pri_{fuel} = \sum_{t=1}^{24}\sum_{i=1}^{n_{CHP}} c_{Gas}^{\mathrm{t}} \times f_{CHPi}(P_i^{\mathrm{t}}) \times \Delta t + \sum_{t=1}^{24}\sum_{i=1}^{n_{GBi}} c_{Gas}^{\mathrm{t}} \times F_{GBi}^{\mathrm{t}} \times \Delta t \tag{2}$$

Where fCHPi is the consumption characteristic function of ith micro turbine , Pi is the power output of ith micro turbine (kW), c t Gas is the gas price at moment t ($/kWh),F t GBi is the gas consumption of ith gas boiler at moment t (kW).

The power purchase costs of multi energy interconnected region with the grid are shown in (3).

$$pri_{Grid} = \sum_{1}^{24} c_{Grid}^{\mathrm{t}} \times P_{Grid}^{\mathrm{t}} \times \Delta t \tag{3}$$

Where c t Grid is the electricity purchasing price at moment t ($/kWh), P t Grid is the exchange power between multi energy interconnected region and the grid at moment t (kW).

The network losses costs in multi energy interconnected region are shown in (4).

$$pri_{loss} = \sum_{t=1}^{24}\sum_{\mathrm{i}=1}^{n} \left| \frac{\Delta U \times \Delta U^{*}}{Z^{*}} \right| \times c_{Grid}^{\mathrm{t}} \times \Delta t \tag{4}$$

Where ΔU is the terminal voltage difference of the network line i, ΔU* is the conjugate of ΔU, Z* is the conjugate of the impedance of the network line i(Ω), c t Grid is the electricity purchasing price at moment t ($/kWh), i is the line number of the multi energy interconnected region network， n is the total number of lines in the network.

2.2. Model Constraints

Constraints of the model include capacity and operation constraints of the energy supply and storage equipment, the balance constraints of power, space heat, hot water, space cooling and refrigeration load and the network constraints, which include the power flow constraints between customers and distribution network and node voltage constraints of the distribution network.

2.3. Solution Method for the Model

Since there are various kinds of energy supply and storage equipment in the optimization model, large numbers of sparse matrix elements will occur when listing the constraints matrix and the solving process will become extremely long if global solution space searing algorithms like genetic algorithm or particle swarm optimization algorithm are used[4-5]. Interior point method is able to solve large scale nonlinear optimization problems quickly by making full use of the sparsity of its modified matrix. Since interior point method has the advantages of handling sparse matrix in solving the optimization model, this paper applies interior point method with Hessian matrix iteration to solve the model in this paper.

3. Case study

The case studies were coded using MATLAB R2014a, with the energy supply and storage equipment of micro turbines, waste heat boiler, absorption chiller, electrical chiller, gas boiler, battery, refrigeration (hot water) storage[6-8], air conditioner and distributed solar system. The multi energy interconnected region exchanges power with external power network, and the gas needed in the region is all bought from the municipal gas company considering that there is no gas production in the multi energy interconnected region. The case studied is a multi-energy supply region located in the eco-city of Tianjin Binhai new area, with the distribution network of 10kV and an energy station located at node 16. The energy supply center of the region is the energy station, which provides multi-energy for surrounding public institutions and buildings marked in green. The topology is shown in Fig. 1.(a). Fig. 1.(b).shows the day-ahead forecasting load curve of public institutions and buildings around the energy station marked in green in the topology. The natural gas prices is converted from 0.53$/m3 to 0.055$/kW·h with the gross heating value of 8571 kcal/m3. The parameters of the energy supply and storage equipment in the case are shown as Table 1 and Table 2

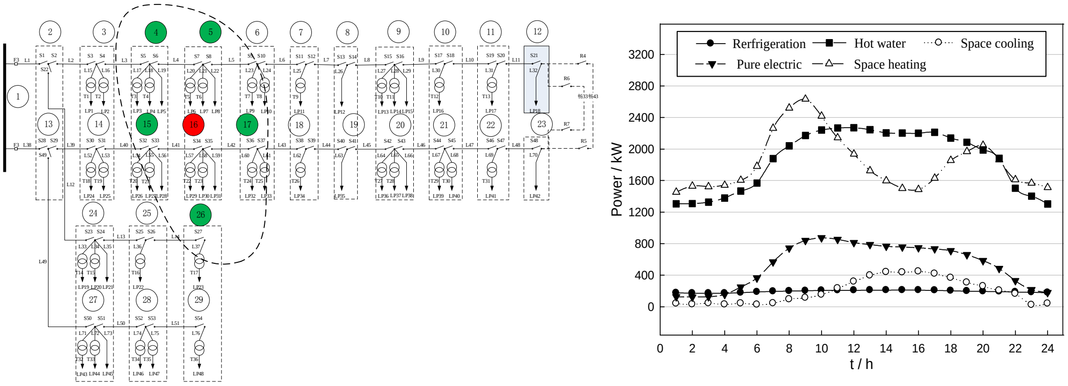

Fig. 1. (a) Topology of multi-energy supply region; (b) Day-ahead forecasting load curve of surrounding public institutions and buildings

Table 1. The coefficients of energy supply equipment

Equipment	Parameter	Value	Equipment	Parameter	Value
Capstone C1000 Micro Turbine Systems	Maximum Power Output $P_{c1000,max}$	1000kW	Electrical Chiller	Maximum Power Input $P_{chil,max}$	600kW
	Nominal Efficiency η_{c1000}	0.33		Nominal Efficiency COP_{chil}	4.0
Waste Heat Boiler	Maximum Power Input $P_{EB,max}$	2400kW	Air Conditioner	Maximum Power Input $P_{cond,max}$	1200kW
	Nominal Efficiency η_{EB}	0.8		Nominal Refrigeration Efficiency EER_{cond}	2.6
Absorption Chiller	Maximum Power Input $P_{AC,max}$	2400kW		Nominal Heating Efficiency COP_{cond}	3.1
	Nominal Efficiency COP_{AC}	1.2	External Network	Maximum Power Purchasing $P_{Bus,max}$	1800kW
Gas Boiler	Maximum Power Input $P_{GB,max}$	1500kW	Distributed Solar System	Maximum Power Generation $P_{DG,max}$	187.8kW
	Nominal Efficiency η_{GB}	0.9			

Table 2. The coefficients of energy storage equipment

Equipment Parameter	Lead-Acid Battery	Thermal Storage Tank	Chilled Water Tank
Charge Efficieny	0.97	0.95	0.95
Discharge Efficieny	0.97	0.95	0.95
Maximum Charge Rate	0.2	0.2	0.2
Maximum Discharge Rate	0.3	0.2	0.2
Self Discharge Rate	0.02	0.03	0.03
Maximum State Of Charge	0.9	0.9	0.9
Minimum State Of Charge	0.2	0.1	0.1
Capacity	200kw·h	1000kw·h	600kw·h

The optimal dispatch schedule of the energy station can be made by solving the proposed day-ahead dispatch model and the results are shown in Fig.2.

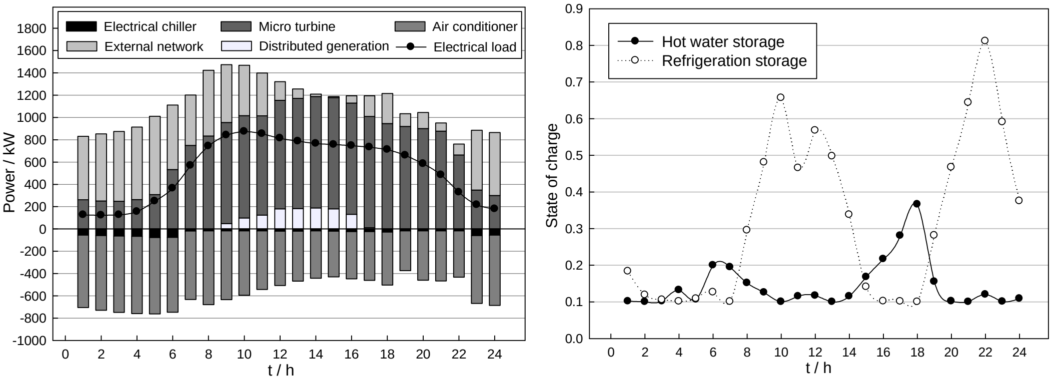

Fig.2. (a) The optimal dispatch schedule of the energy supply equipment in the energy station

(b) The optimal dispatch schedule of the energy storage equipment in the energy station

After adopting the proposed control strategy in this paper , the daily operation cost of the multi energy interconnected region decreasing 24% than the not optimized strategy,12% than the electricity by heat strategy and 9% than the heat by electricity strategy respectively shown in Fig.3,thus demonstrates the effectiveness of the proposed economic dispatch schedule.

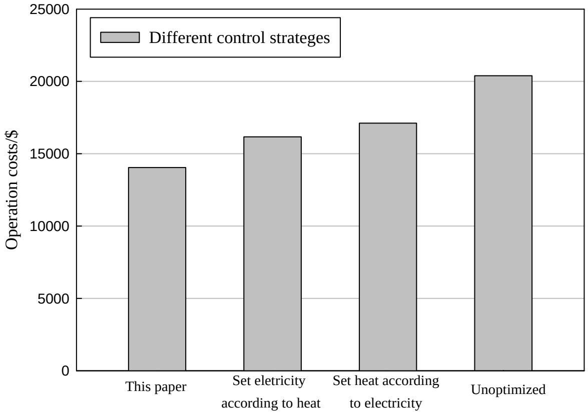

Fig.3. Operating cost of the system under different scheduling strategies

4. Conclusions

This paper focus on the problem of making optimal economic dispatch schedule for the multi energy interconnected region and establishes a day-ahead optimal economic dispatch model based on centralized and interconnected energy exchange framework. Since the optimization is carried out in the region, the constraints of regional network topology are taken into account, and in the optimization objective, the network losses costs are taken into account. The model is solved by the interior point method with Hessian matrix iteration. A case study shows that by performing the schedule made by the dispatch model, he daily operation cost of the multi energy interconnected region decreasing remarkably, thus demonstrates the effectiveness of the proposed economic dispatch schedule.

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