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A DESIGN OF INTEGRATED ENERGY SYSTEM BASED ON OPTIMISTIC AND PESSIMISTIC CRITERION UNDER UNCERTAINTY

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ABSTRACT

A two-stage program for the integrated energy system (IES) based on Optimistic and Pessimistic criterion is presented in this paper, considering the uncertainty of energy price. Then, based on the framework of the energy hub in IES, the model of energy management is well formulated to minimize the total cost according to the Optimistic and Pessimistic criterion. Furthermore, the proposed model is solved by Aimms solver. Finally, a case study based on Optimistic and Pessimistic criterion is employed to examine the characteristic of the proposed model for the decision-maker.

Keywords: energy hub, integrated energy system, optimistic and pessimistic criterion, uncertainty.

1. INTRODUCTION

With the increasing of the energy demand in the modern society, the problem of energy shortage is increasingly serious, which brings great harm to the sustainable development of human society. The integrated energy system (IES) can effectively integrate the distributed generation unit, combined cold heat and power supply (CCHP) system, load, energy storage device and control system, so as to meet the needs of users for the combined energy supply of electric energy, thermal energy and cool, and finally form a flexible system that can be connected to the grid and run independently [1].

Recently, the development of the energy hub-based systems has received the wide attention, which can effectively describe the interactions of multiple-energy coupling [2]. Considering the system uncertainties, a two-stage stochastic program of multiple energy carriers is proposed, where the objective is to minimize the investment and operational costs in the context of the energy hub system [3]. In Ref. [4], the optimal operation of an energy hub in consideration of the uncertainties in demand, wind generation and electricity price is proposed, in which the operation cost, reliability terms, and greenhouse gas emission were captured in the objective function.

In previous studies that investigated IES design, the uncertainty of the electricity price, demand and wind power is more concerned. Less consideration is given to the uncertainty of natural gas price in IES. In this paper, with the consideration of uncertainty of electricity price and nature gas price, Optimistic, Pessimistic and Hurwicz criteria is adopted to minimize the cost objective, which aims to capture the possible decision-maker attitudes and lead to more informed decisions.

This paper is organized as follows; Section 2 presents the formulation of the optimization model for IES design under uncertainty and optimistic and pessimistic criteria for decision-making considered. Case study and results are represented in Sections 3 and 4, respectively. The conclusion is presented in Section 5.

2. A TWO-STAGE PROGRAMMING MODEL FOR IES DESIGN UNDER UNCERTAINTY

2.1 Energy Hub

Fig. 1 shows the general model of the energy hub. The energy hub receives nature gas and electricity as input and delivers the required electricity and thermal energy to the load. This physical element of the energy hub is contained PV, battery, transformer, CHP, gas boiler and heat storage.

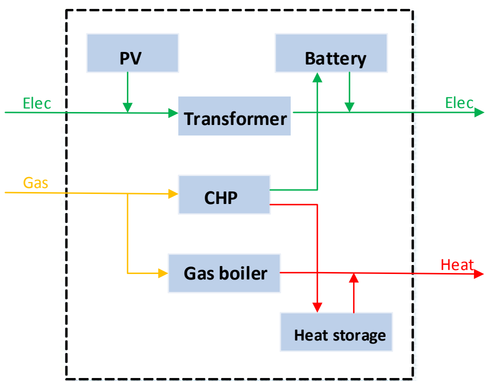

Fig. 1. Energy hub

2.2 Uncertainty parameters and decision variables

2.2.1 Uncertainty parameters

In this section, the parameters of the uncertainty are real-time electricity price and nature gas price. In order to characterize the uncertainty, BP neural network is used to forecast the nature gas price and forecasting error represents the uncertainty. For the uncertainty of real-time electricity price, the line of price-based is referred [5], the uncertainty of the real-time electricity price is characterized by disturbance. The forecasting error of nature gas price and the disturbance of the real-time electricity price are modeled by Gaussian probability density function (PDF) in (1).

$$f(x) = \left(\frac{1}{\sigma\sqrt{2\pi}}\right) \times \exp\left(-\frac{(x-\mu)^2}{2\sigma^2}\right) \quad (1)$$

where μ and σ are average and standard deviation of the forecasting error of nature gas price and disturbance of the real-time electricity price, respectively.

2.2.2 Two-stage decision variable

The first-stage decision variables are including the selection and the sizing of the IES technologies i.e. the capacity of each equipment (kW for conversion devices, kWh for storage devices, kWp for PV). At the second-stage, operating decision variables are including the output power of each conversion device, energy stored in storage and amount of nature gas and electricity purchased at each time period.

The IES design takes the economy as the objective function. Total cost consists of equipment investment cost and equipment operation cost, the formulation as follows:

$$f_c = C_I^{ann} + C_O^{ann} \quad (2)$$

where C_I^{ann} is the investment cost of total cost, C_O^{ann} is the annual operating cost of equipment. The specific formula calculation is referred [6].

2.3 Decision-making criteria

The two-stage decision variables have been discussed in section 2.2.2. Next, selecting the suitable model's objective function is determined in this section. The criteria and their corresponding formulation are described in the following subsections .

2.3.1 Optimistic criteria

The first criteria considered is the Optimistic criteria. The aim is to minimize the minimum costs. It appeals the extremely optimistic and risk-seeking decision-maker towards the uncertainty. However, it ignores the possibility of extreme costs while minimizing the total system cost. This criteria is expressed in Eq. (3).

$$\begin{aligned} &\min\ z_1 = C_I^{ann} + \sum_{s\in S} \xi_s \cdot C_{Os}^{ann} \\ &s.t.\ \ \sum_{s\in S} \xi_s \geq 1 \end{aligned} \tag{3}$$

where ξ_s is a binary variable that is equal to 1 for at least one scenario. $s \in S$ is scenario of uncertainty parameter.

2.3.2 Pessimistic criteria

The Pessimistic criteria is full contrast with Optimistic criteria. It reflects the point of view of an extremely pessimistic and risk-averse decision-maker towards uncertainty. The objective is to minimize the maximum total system cost. The formulation is presented in Eq. (4).

$$\begin{aligned} &\min\ z_2 \\ &s.t.\ \ z_2 \geq f_{cs} \quad \forall s \in S \end{aligned} \tag{4}$$

2.3.3 Hurwicz criteria

Hurwicz criteria is seeking a compromise between optimistic and pessimistic criteria, The weight coefficient λ is used to weigh the Optimistic and Pessimistic criteria. Also, λ is represented the optimism level of decision-maker. The formulation of the Hurwicz criteria is given in Eq. (5)

$$\begin{aligned} &\min\ Hurw_\lambda = \lambda \cdot z_1 + (1-\lambda) \cdot z_2 \\ &s.t.\ \ z_2 \geq f_{cs} \quad \forall s \in S \\ &\qquad \sum_{s\in S} \xi_s \geq 1 \end{aligned} \tag{5}$$

3. CASE STUDY

The proposed model is applied to an IES with one energy hub. In this system, mathematical expressions and parameter settings of energy hub constraints are referred [6].

The historical nature gas monthly price data [7] is used to predict the nature gas monthly price for the year ahead by BP neural network. Ten scenarios are generated based on the PDF of forecasting error of the nature gas monthly price. Then, it is selected the minimum, medium and maximum nature gas prices to represent the Optimistic, Hurwicz and Pessimistic case. Also, basic data of the real-time electricity is from Ref. [5], using the normal PDF with mean value equal to the basic price and standard deviation equal to the 10% basic price. Then, method mentioned above is used to select corresponding real-time electricity price.

The nature gas price and real-time electricity price under Optimism, Hurwicz and Pessimism case are given in Fig.2 and Fig.3.

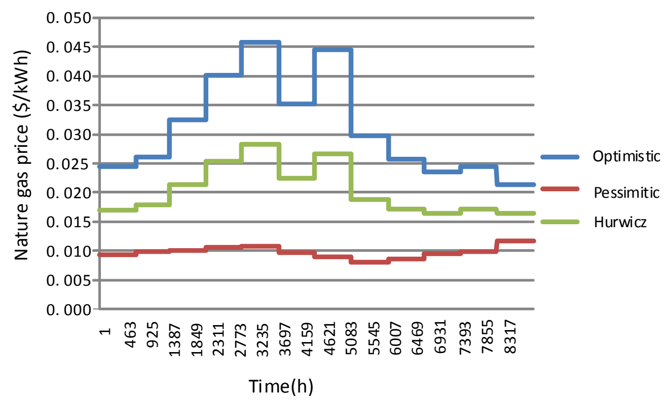

Fig. 2. Nature gas price

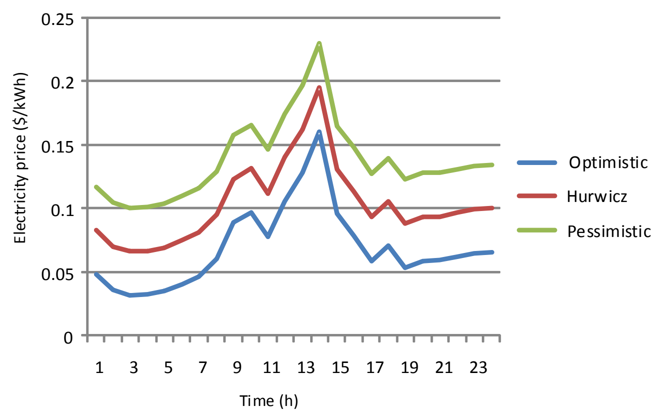

Fig. 3. Real-time electricity price

4. RESULTS AND DISCUSSION

In this section, the two-stage IES design model is applied for the decision-making criteria and the results regarding the optimal IES design and their performance are analyzed. The proposed model is a MILP which is implemented by Aimms solver.

Case 1. Optimistic designing

In this case, the objective is Eq. (3), minimizing the real-time electricity price and nature gas price. This case ignores the extreme costs and is suitable for the extremely optimistic decision-maker.

Case 2. Pessimistic designing

In this case, the objective is Eq. (4). This case is very conservative and risk-averse. It requests that the total system cost should not exceed the expected value.

Case 3. Hurwicz designing

In this case, the objective is Eq. (5). Regarding the weight coefficient, λ is used to equal to 0.5 to form the trade-off between the Optimistic and Pessimistic objectives. Table 1 summarizes the total cost and results of programs under case 1, case2 and case 3.

Table 1

Comparison of different objectives under three cases

Case	Case 1	Case2	Case3
Total cost ($)	68766	1409325	1077547
CHP capacity (kW)	0	419.075	289.017
Gas boiler capacity (kW)	4000	3275	3500

From case 1, it can be found that single gas boiler whose capacity is 4000kW can meet the requirement for the optimistic decision-maker. And it minimizes the total cost at the cost of the extreme case. For case 2, it can be seen that CHP (419.075kW) and gas boiler (3275kW) are combined to satisfy the requirement for the pessimistic decision-maker. It is conservative at the cost of the economy. However, for the case 3, it is a compromise between the case1 and case 2, it combines the economy and conservatism. By obtaining multiple IES designs, decision-makers are able to make trade-off and select one design that matches most closely their preferences.

5. CONCLUSIONS

This paper presents a two-stage model for the program of cost-optimal IES under the uncertainty of energy price. Optimistic, Hurwicz and Pessimistic criteria are formulated as the model's objective functions, which can characterize the attitude of decision-maker towards uncertainty. Finally, the model is applied to an energy hub and decision results are analyzed through an example.

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REFERENCE

[1] H.J.Jia, Y.F.Mu, X.D.Yu. Thought about the integrated energy system in China. Electric Power Construction, 2015, 36(1):16-25.

[2] X.Zhang, M.Shahidehpour, A.Alabdulwahab, et al. Optimal expansion planning of energy hub With multiple energy infrastructures. IEEE Transactions on Smart Grid, 2015, 6(5):2302-2311.

[3] M.H.Shams, M.Shahabi, M.E.Khodayar. Stochastic day-ahead scheduling of multiple energy carrier microgrids with demand response. Energy, 2018.

[4] S.Pazouki, M.R.Haghifam, A.Moser. Uncertainty modeling in optimal operation of energy hub in presence of wind, storage and demand response. International Journal of Electrical Power & Energy Systems, 2014, 61:335-345.

[5] X.L.Jin, Y.F.Mu, H.J.Jia, et al. Optimal day-ahead scheduling of integrated urban energy systems. Applied Energy, 2016, 180:1-13.

[6] B.W.Hong. Research on dispatch model and method of microgrid.Tianjin university, 2014.

[7] https://www.eia.gov/naturalgas/monthly.com.