International Conference on Applied Energy 2019
Aug 12-15, 2019, Västerås, Sweden
Paper ID: 0011

RESEARCH ON BIDDING STRATEGY BASED ON EVALUATION MECHANISM FOR PEER-TO-PEER ENERGY TRADING IN MICROGRID

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ABSTRACT

Under the liberalization of the retail electricity market, peer to peer (P2P) energy trading between households in microgrid are more economical. This paper discusses the bidding strategy based on evaluation mechanism for P2P energy trading in microgrid. The main focus is how to reduce the cost of electricity consumption of households and the impact caused by the intermittent and volatility of distributed sources such as photovoltaics (PV) by limiting the selfish behaviors of households in microgrid. Firstly, based on the characteristics of the electricity market, an evaluation mechanism based on the analytic hierarchy process (AHP) for energy auction is proposed to evaluate the energy service level of households and constrain the selfish behavior of households in microgrid. Secondly, the bidding strategy based on evaluation mechanism for P2P energy trading in microgrid is established. Moreover, based on the economic principle, the electricity supply and demand relationship of the household is quantitatively determined by the Household Electricity Supply and Demand Ratio (HESDR) and the energy valuation of household is defined. Finally, through the simulation of actual examples, the effectiveness of the proposed model in reducing the net cost of electricity for households and the impact on the grid are verified.

Keywords: electricity market; peer-to-peer; household electricity supply and demand ratio; evaluation mechanism; electricity auction

NONMENCLATURE

Abbreviations	
P2P	Peer to peer
PV	Photovoltaics
AHP	Analytic hierarchy process
HESDR	Household Electricity Supply and Demand Ratio
MS	Microgrid server
OQP	Optimal quotation point
Symbols	
$e_i^{(3)}$	Index weight vector of the third layer
$e_i^{(2)}$	Index weight vector of the second layer
e_i	Combination weight vector
K_i^h	HESDR of household i in the h timeslot
$P_{PV,i}^h$	PV production of household i in the h timeslot
$P_{load,i}^h$	Load demand of household i in the h timeslot
P_G^{buy}	Purchase electricity price from the grid
P_G^{sell}	PV grid-connected price
b_i	Quotation of the electricity of the household i
V_i^h	Valuation of the electricity of the household i in the h timeslot
S_i	Evaluation coefficient of the household i
v_i^h	Optimal valuation of the electricity of the household i in the h timeslot

1. INTRODUCTION

In recent years, with the large amount of PV access on the retail side, clean energy has been brought to the households. However, the PV power generation system has the characteristics of randomness, intermittent and volatility, which have a great impact on the safe and stable operation of the power grid [1]. Microgrid is a good form to organize P2P energy trading among PV households and promote on-site consumption of the distributed PV [2]. However, this also puts higher demands on the orderly competition of the electricity market and the reasonable price formation mechanism. In this study, a bidding strategy model for P2P energy trading based on evaluation mechanism is proposed. And, the microgrid server (MS) collects the quotations of each household and sorts them. Moreover, based on the principle of economics, the electricity supply and demand relationship of the household is quantitatively represented by HESDR [2]. Through this model, it is possible to make the sellers with better evaluation have an advantage and priority to trade, which plays a role in credit and qualification constraints on the electricity sellers in the electricity market, and promote the sound development of the electricity market [3].

2. EVALUATION MECHANISM FOR ELECTRIC POWER BIDDING [4]

In this paper, the judgment matrix W is constructed by using the T.L.Saaty 1-9 ratio scale method [5]. Based on AHP [5], the first layer is the target layer, which concludes one sub-item named comprehensive score, indicated by A. The second layer is the criterion layer, which contains technical index and service index, which are represented by B_1 and B_2 respectively. The third layer is the index layer which contains six indexes. Among them, the voltage deviation index, voltage fluctuation index and voltage harmonic distortion rate are subordinated to technical index B_1 in the criterion layer, denoted by C_1, C_2 and C_3 respectively; and power supply duration guarantee, power supply punctuality and transaction believability are subordinated to service index B_2 in the criterion layer, denoted by C_4, C_5 and C_6.

These indicators are independent of each other, and the weight of each index are quantitatively determined. When the judgment matrix satisfies the consistency requirement, the weight coefficient of each indicator determines: the third layer of each index weight vector $e_i^{(3)}$, the second layer of each index weight vector $e_i^{(2)}$ and the combined weight vector is $e_i = e_i^{(2)} * e_i^{(3)}$.

Through the analysis of historical transaction information, MS determines the evaluation value $p_i (0 \le p_i \le 1)$ of each evaluation index C_i, and then obtains the target layer comprehensive score *A*, which can be expressed as:

$$A = f(p) = \sum_{i=1}^{n} e_i p_i \tag{1}$$

Among them, the comprehensive score *A* is located in the interval $[0,1]$. However, when the household bids for the quotation, the lower the quotation, the easier it is to be selected by the electricity consumer. Therefore, the auction evaluation coefficient *S* can be defined as follows:

$$S = 1 - A \tag{2}$$

3. AUCTION MODEL BASED ON EVALUATION MECHANISM FOR P2P ENERGY TRADING

3.1 Electricity valuation for electricity seller

According to economic principles, the price of goods is determined by the relationship between supply and demand [6]. Inspired by the overall power supply and demand ratio of the whole community microgrid proposed in [2], this paper considers the difference of transaction price between households, quantitatively constructs the relationship between supply and demand of households and determines the electricity valuation of households.

$$K_i^h = \frac{P_{PV,i}^h}{P_{load,i}^h} \tag{3}$$

The energy evaluation V_i^h of electricity seller *i* during the *h* timeslot satisfies the following relationship:

$$V_i^h = f(K_i^h) = \begin{cases} \dfrac{P_G^{buy} P_G^{sell}}{(P_G^{buy} - P_G^{sell})(K_i^h - 1) + P_G^{sell}} & 1 < K_i^h \le 2 \\ P_G^{sell} & K_i^h > 2 \end{cases} \tag{4}$$

3.2 Optimal bidding function based on evaluation mechanism for electricity seller

Based on the evaluation mechanism, evaluation coefficient *S* needs to be considered [7]. Therefore, the prospective earnings of the seller *i* can be expressed as:

$$G_i(b_i) = (b_i - V_i) \prod_{j=1}^{n} P(b_j S_j > b_i S_i), j = 1, 2, \ldots, n (j \ne i) \tag{5}$$

For the seller *i*, the prospective earnings function is a convex function, so when the prospective earning is the largest, the derivative of the prospective earning function is 0 at the derivative $b_i = v_i$, namely:

$$\left.\prod_{j=1}^{n} P(b_j S_j > b_i S_i)\right|_{b_i = v_i} + (b_i - V_i) \left[\left. \frac{d\left[\prod_{j=1}^{n} P(b_j S_j > b_i S_i) \right]}{db_i} \right|_{b_i = v_i} \right] = 0 \tag{6}$$

4. CASE STUDY

4.1 Basic data

This paper cites cluster data consisting of five distributed PV households in a community in [8]. The households in the cluster are equipped with complete measurement systems and information communication equipment. The local electricity purchasing price is 0.91 yuan from the grid, and the PV grid-connected electricity price is 0.3949 yuan. The PV and load power curves of each household are as shown in Fig.1 and Fig.2.

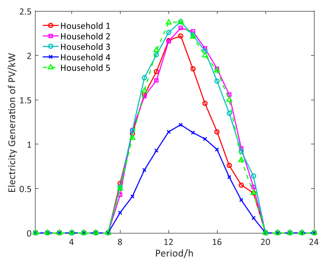


Fig 1 Generation of PVs

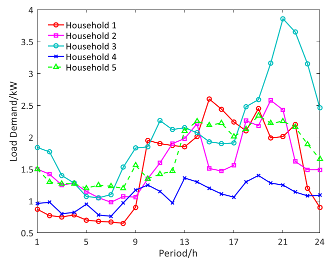


Fig 2 Loads demand

The electric energy transaction occurs when the PV power generation is positive. Therefore, the timeslots from 8th to 19th are selected to analyze the household strategies. According to formula (3), the HESDR of each household in microgrid is as shown in Fig.3.

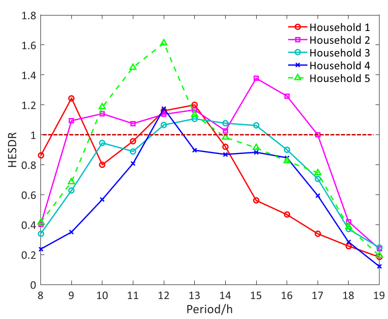


Fig.3 HESDR in different timeslots

4.2 Analysis of bidding results based on evaluation mechanism

Considering that technical indicators and service indicators are equally important, and the weight vector of criterion layer to target layer is $e_0 = [0.5, 0.5]$. Then, the combination weight vector of the index layer can be recorded as: $e_1 = [0.055, 0.27778, 0.1666]$ and $e_2 = [0.26923, 0.19231, 0.0384615]$.

In order to reflect the difference in scoring of each household, the historical score of each household is generated by a uniform random number method. MS determines the evaluation coefficients of five households based on the AHP, which are 0.5247, 0.3718, 0.3902, 0.8434, and 0.6071 as the results of the evaluation mechanism and participate in the bidding.

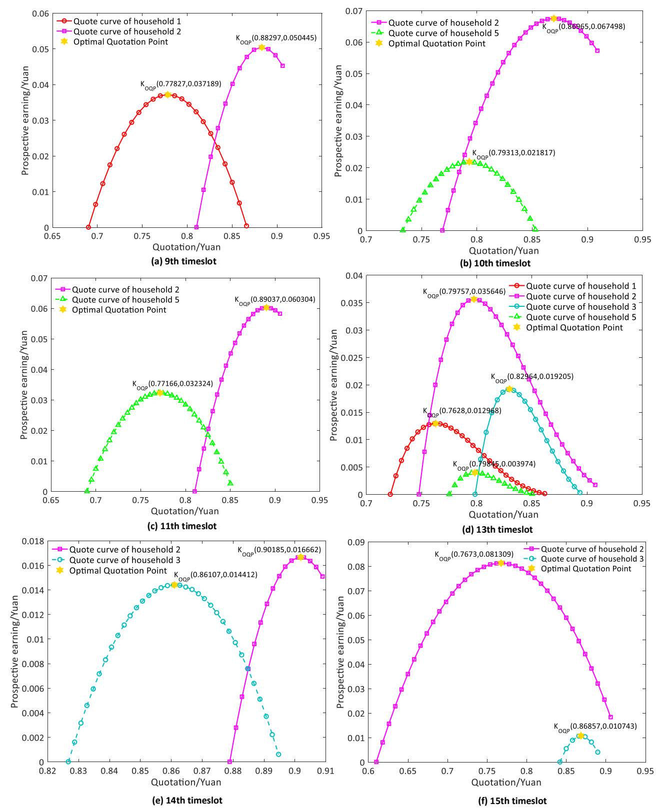


Fig 4 The bidding results based on evaluation mechanism

The bidding results of each household in each timeslot are shown in Fig.4. Taking 9th timeslot as an example. During this timeslot, the HESDR of household 1 and 2 is larger than 1, who are the electricity sellers, and the household 1 and 2 are estimated to be 0.69 and 0.8103 according to formula (4); The HESDR of household 3, 4, and 5 are smaller than 1，who are the electricity consumers. The optimal quotation point (OQP) of the household is on the maximum value corresponding to the abscissa of the prospective earning function, which is represented by a yellow hexagon in the figure. According to the simulation analysis, the household 1 preferentially supplies power. After the net electricity of household 1 has been consumed, the household 2 begins to supply. The analysis process of the remaining 10-16th timeslots is similar to the 9th timeslot. Among them, in the 12th timeslot, since the HESDR of the five households are all larger than 1, there is no need to bid, and the surplus electricity is preferentially stored in the energy storage, and then sold to the power grid. In the 16th timeslot, only the household 2 has excessive electricity, so there is no need to bid.

After that, households receive the processed bidding result from the MS and reschedule their energy sources and loads accordingly all in one day, as shown in Fig.5.

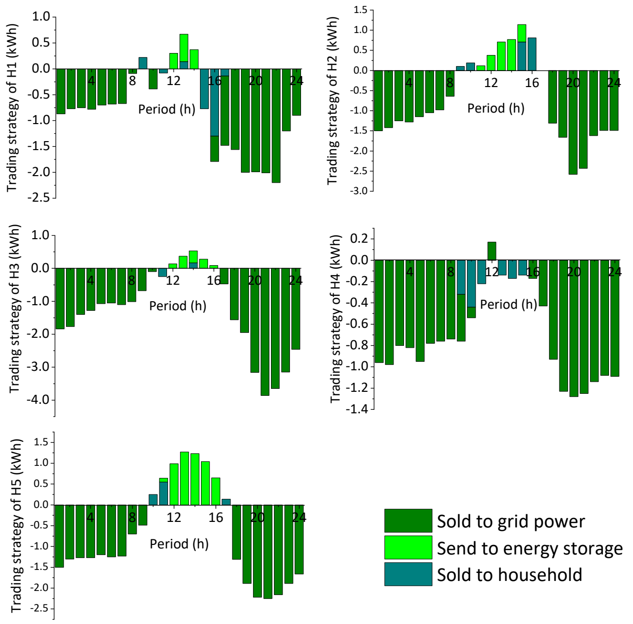
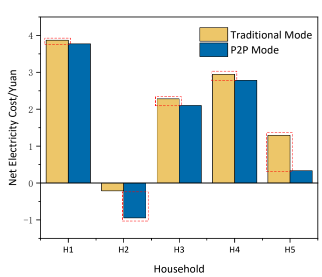


Fig 5 Trading strategy of 5 households in different timeslots

4.3 Comparative analysis of different strategies

This paper compares P2P mode with the traditional mode in both aspects of the net electricity cost and the interaction with the power grid. As shown in Fig.6, the net cost of electricity for all households in P2P mode is lower than the traditional mode. Especially for the household 2, household 2 is in a profitable state on the trading day, and the profit of the P2P mode is about 347% higher than that of the traditional mode.



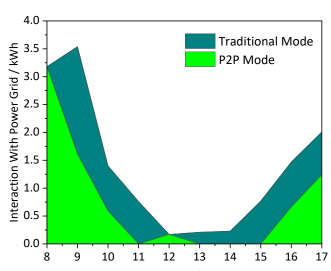


Fig 6 Comparison of net cost   Fig 7 Comparison of interaction

In terms of the impact on the power grid, as shown in Fig.7, in the trading timeslot (8-17), the interaction electricity with power grid is smaller than the traditional mode because the P2P mode can better realize the local consumption of PV power.

5. CONCLUSION

This paper establishes a bidding model based on the evaluation mechanism for P2P energy trading in microgrid. The evaluation mechanism serves as a feedback to the historical service level of the electricity seller, which enables the electricity seller with better evaluation in an advantage and gives priority to trade. Compared with the existing mode, this model can improve the level of PV interaction in microgrid, which helps to reduce the cost of electricity for households and the impact on the grid.

ACKNOWLEDGEMENT

This project was supported by National Key R&D Program of China (No. 2018YFB0905000) and Qingdao Ocean Engineering Equipment and Technology Think Tank Joint Project (201707071003). This study was conducted in cooperation of APPLIED ENERGY UNiLAB-DEM: Distributed Energy & Microgrid. UNiLAB is an international virtual lab of collective intelligence in Applied Energy.

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