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A Block-Based Medium-Long Term Energy Transaction Method

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***Abstract*—This letter proposes a novel medium-long term energy transaction method, in which the energies are traded in block and their duration and shiftable ability can be distinguished and reflected. In the bilateral auction mechanism, the users are motivated to accommodate consuming modes by scheduling the shiftable loads. The case studies have shown that the method helps to promote the integration of renewable power and improve the social benefits.**

***Index Terms*—Energy transaction, load block, renewable generation, shiftable load.**

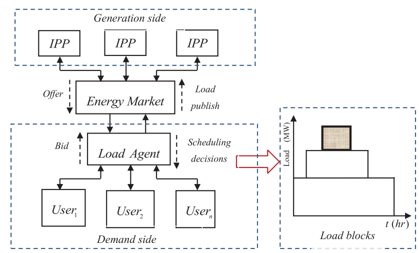

Fig. 1. Framework of energy transaction based on block.

I. INTRODUCTION

CONVENTIONAL energy transactions are generally settled by time. The energy price is considered to be constant in one time interval and changes with different time intervals. However, the continuous property of electric energy is ignored, both in generation and demand [1]. According to the different durations, the load can be divided into the base, intermediate and peak parts. Meanwhile, there are various generation techniques such as nuclear, thermal, gas, renewable, etc. The base load runs continually and the corresponding committed units such as the nuclear do not need to turn on/off or regulate frequently, so the energy cost is relatively low and the base-load consumers should pay cheap bills. On the contrary, the peak load is carried by the generators such as gas units that trace load changing and regulate frequently even turn on/off. It is therefore evident that these generators with high costs make more contributions to the balance of system and ought to be granted to high returns. Consequently, the value of energy is closely related to its duration.

It has become a widespread consensus that the peak periods are with higher marginal prices while the valley periods are with lower ones. Moreover, consumers with shiftable loads can make contributions to grid operation via peak-load shaving and they should be rewarded [2]. On the other hand, the outputs of renewable generation such as wind or solar power are uncontrollable. These energies should be rewarded low returns because they cannot trace the load changing.

It can be observed that the value of energy is therefore related to shiftable ability as well. Considering the transactions with various durations and shiftable abilities, a block-based medium-long term energy transaction method is introduced according to the theory of horizontal auction [3], to resolve the problem of energy transaction in a more rational way.

II. MODEL

The proposed medium-long term transaction framework is illustrated in Fig. 1, which would avoid the risk in spot market and improve the stability of system in generation supplying [4]. The Load agent (LA) participates in the transaction with appropriate bidding strategies as the aggregator of multiple users. It collects consuming information including quantity of non-shiftable and shiftable loads before bidding, and releases the results to users after clearing. On the generation side, the independent power producers (IPPs) choose to offer the blocks based on their operating modes.

The LAs and IPPs aim to maximize their benefits. The offer/bid strategies of them are not discussed for lack of space, and only the main steps of transaction are provided as follows:

Step 1) The users submit medium-long term electric energy consuming information to LA. For the shiftable load, the shiftable time window, the energy quantity and the maximal power should also be provided.

Step 2) The LA gathers all the users' information, integrates the load, and then divides it into a few blocks horizontally as shown in Fig. 1. Some of the blocks can be declared as shiftable load (represented by the shadow block), which can cooperate with the uncontrollable generation and get cheaper purchasing prices.

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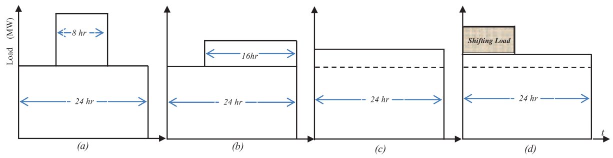

Fig. 2. Four cases of integrated load blocks submitted by LA.

Step 3) Each IPP chooses one or more load blocks to offer based on its operating mode. In general, the nuclear and the large thermal units are more suitable for the base load blocks with continuous time while the peaking units, such as the gas generation, tend to select the blocks with short durations to obtain more revenue via their flexibility. For renewable generation, the credible output can also participate in the competition of continuous time blocks [5].

Step 4) The market operator clears the transaction block by block. Firstly, non-shiftable load blocks are cleared according to durations from long to short, and then the shiftable blocks. For each block, the clearing model is shown in (1)–(3). The objective function is maximizing the social benefits, as shown in (1). The market clearing prices (MCPs) of blocks are the Lagrange multipliers of (2). Each block is settled with corresponding MCP independently.

$$Max \left\{ \sum_{m=1}^{M} P_m^{bid} Q_m^{bid} - \sum_{i=1}^{I} \sum_{n=1}^{N} P_{i,n}^{offer} Q_{i,n}^{offer} \right\} \tag{1}$$

$$s.t. \ \sum_{m=1}^{M} Q_m^{bid} - \sum_{i=1}^{I} \sum_{n=1}^{N} Q_{i,n}^{offer} = 0 \tag{2}$$

$$f_Q(Q_m^{bid}, Q_{i,n}^{offer}) \le 0. \tag{3}$$

In them, the superscripts *bid* and *offer* are adopted to distinguish purchasers and suppliers. P and Q represent the price-quantity pair. m and n are the indexes of block in bidding curves. i is the index of IPP. The corresponding capitalized labels are the maximum of indexes. The constraint in (2) describes the balance between supply and demand. The constraint in (3) represents the general constraints in clearing problems, including the upper and lower limits of variables, constraints of winning blocks, and so on.

III. Case Study

The case studies are carried out on a simple system. The offer of various IPPs is provided in Table I and each IPP chooses one or more blocks to offer based on their own operating modes. For the producers with uncontrollable output, it is necessary to mark the beginning and ending time of the block such as 1–8 hr for the wind producers. The following cases of integrated load scheduled by LA are considered, which are also shown in Fig. 2.

Case a: $100\ \text{MW}(1-24\ \text{hr}) + 60\ \text{MW}(9-16\ \text{hr});$
Case b: $100\ \text{MW}(1-24\ \text{hr}) + 30\ \text{MW}(9-24\ \text{hr});$
Case c: $120\ \text{MW}(1-24\ \text{hr});$
Case d: $110\ \text{MW}(1-24\ \text{hr}) + Q_{shift}.$

The shiftable time window of Q_{shift} is 1–24 hr and the total quantity is 240 MWh while the maximal capacity is 50 MW.

Based on the offering load profiles, the winning quantities, MCPs and settled expenses can be calculated by the queuing method. The clearing results in the four cases are shown in Table II. Note that the symbols of N, T, G, and W stand for the nuclear, thermal, gas, and wind power producers respectively.

Although the quantities of the total energy are the same in the four cases, the expenses are very different due to the different characteristics of load blocks. In Case a, there is a peak load block and the duration of it is as short as 8 hr. The MCP reaches as high as 55$/MWh. In Case b, the duration is extended to 16 hr and the MCP is reduced to 45$/MWh. In Case c, there is only the base load block and the MCP is 30$/MWh.

The lowest MCP is obtained in Case d. It is because that there is a shiftable load and it can chase the wind power block, which is with lower offer. Once matched by the shiftable load, the wind power can be absorbed and the MCP is reduced as well.

TABLE I
Four Plants Offering Information in Generation Side

Unit Type	Block Duration (hr)	Max Capacity (MW)	Offer Price ($/MWh)
Nuclear Power	24	50	25
Thermal power	24	50	30
	16		40
	8		50
Gas Power	16	50	45
	8		55
Wind Power	24	20	25
	8 (1-8hr)	40	20

TABLE II
Results Analysis in Four Cases

Case	Block	N	T	G	W	MCP ($/MWh)	Expenses ($)	Total ($)
a	24 hr	50	30	0	20	30	72000	98400
	8 hr	0	20	40	0	55	26400	
b	24 hr	50	30	0	20	30	72000	93600
	16 hr	0	20	10	0	45	21600	
c	24 hr	50	50	0	20	30	86400	86400
d	24 hr	50	40	0	20	30	79200	84000
	8 hr	0	0	0	30	20	4800	

IV. Conclusion

The value of energies is related to the duration and shiftable ability in both generation and demand. This letter proposes a novel block-based medium-long term energy transaction method in which participants can offer or bid in terms of their generating characteristics or consuming modes. Moreover, the value of shiftable load can be better reflected. As shown in the case studies, it promotes the renewable energy integration and raises the whole social benefits.

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