Base Data for "Bounded Rationality-Based Dynamic Game for Multiple Virtual Power Plants Considering Different Trading Targets"

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Abstract—**This material presents some base data of a test system in the paper "Bounded Rationality-Based Dynamic Game for Multiple Virtual Power Plants Considering Different Trading Targets".**

A. The Shapley value method

The core idea of the Shapley value is to allocate the revenue according to the contributions of the players. The greater the contribution, the more the revenue. Let $\Omega = \{1, 2, ... n\}$ be the grand coalition of all the players (PV, WT and ESS) and S be a subset of Ω $(S \subseteq \Omega)$. The Shapley value is used to calculate the revenue ϕ_i of the player i within the 'joint unit'.

The formula of the Shapley value allocation is as follows:

$$\phi_i = \sum_S \omega(|S|)\big(v(S) - v(S - \{i\})\big) \qquad (14)$$

$$\omega(S) = \frac{(n - |S|)!(|S| - 1)!}{n!} \qquad (15)$$

where $|S|$ is the number of players in coalition S; $v(S)$ is the 'joint unit' cooperation revenue including player i; $v(S - \{i\})$ is the 'joint unit' cooperation revenue excluding player i; $\omega(|S|)$ is the weighted factor; $n!$ represents all the possible permutations of the players in the 'joint unit'. The term $\big(v(S) - v(S - \{i\})\big)$ is equal to the incremental gain of coalition S brought by player i joining the coalition.

The PV, WT and ESS in the 'joint unit' are denoted as 1, 2 and 3 $(n = 3)$, respectively. $v(1), v(2), v(3)$ represents the revenue of each player, and $v(\{1, 2, 3\})$ represents the total revenue. According to the above formula (14)-(15), the revenue distribution of the 'joint unit' can be obtained.

B. The solution process of dynamic game model

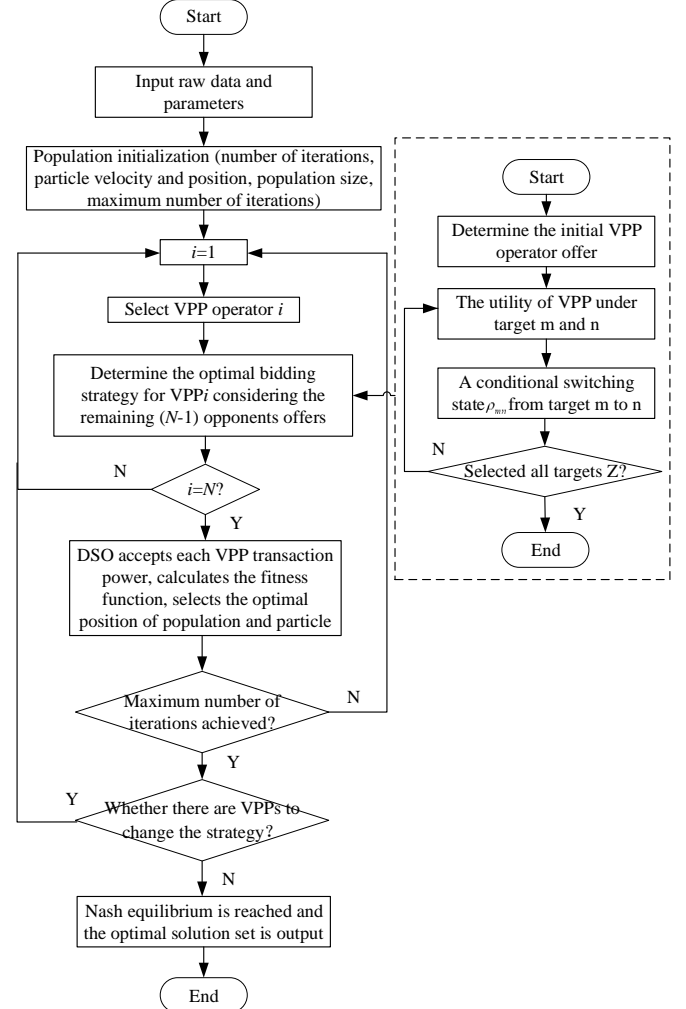The solution process of dynamic game model is shown in Fig. 1.

Fig. 1. Algorithm flowchart of dynamic game.

C. Renewable energy uncertainty modeling

The uncertainty of renewable energy sources, such as wind power, imposes great challenges on the traditional operation and control strategies of power grids. Besides, the uncertainty of RES also affects the bidding strategy of VPPs. To solve this problem, the probability density functions of simulated PV and WT outputs are studied. The output of PV generation is strongly correlated with the solar irradiation. For each time period, the solar irradiation is considered as a random variable and is assumed to follow a beta distribution [30]. Therefore, the output of PV generation also follows a beta distribution.

Similarly, for each time period, the wind speed is assumed to follow a Weibull distribution [31]. Since the output of WT is strongly correlated with the wind speed, the output of WT also follows a Weibull distribution. The probability density functions are given as

$$f(S) = \frac{S\Gamma(\alpha+\beta)}{S_r^{PV}\Gamma(\alpha)\Gamma(\beta)}\left(1-\frac{S}{S_r^{PV}}\right)^{\beta-1} \tag{32}$$

$$f(v) = \frac{k}{c}\left(\frac{v}{c}\right)^{k-1}\exp\left[-\left(\frac{v}{c}\right)^k\right] \tag{33}$$

where $f(S)$ is the Beta probability density function of S; $f(v)$ is the Weibull probability density function of v.

D. Data Configuration

The parameters and the resources inside each VPP are shown in Tables I-III. The one-day (24 h) load of each VPP is composed of the residential load, commercial load, and industrial load. The actual load curve of VPPs, WT curve, and PV curve are shown in Fig. 2. The maximum load variations of RL is 10%.

TABLE I
PARAMETERS OF ESS

Power limit /(MWh)	Capacity limits /(MW)	Charging coefficient	Discharge coefficient	The scheduling cost /(USD/(MWh))
0.3	1.5	0.9	0.9	500

TABLE II
PARAMETERS OF MT

Upper limit /(MWh)	Lower limit /(MWh)	Rate of climb /(MWh)	Power generation cost /(USD/(MWh))	Climbing cost /(USD/(MWh))
0.3	1.5	1	500	200

TABLE III
RESOURCES INSIDE VPPs

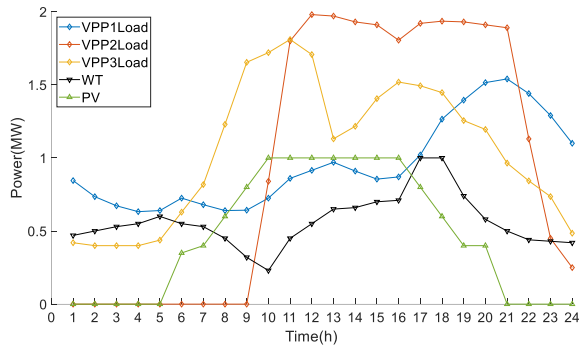| Subject	WT	PV	MT	ESS	RL	Load
VPP1	√	√	√	x	x	√
VPP2	x	√	√	x	√	√
VPP3	√	√	√	√	x	√

Fig. 2. Predicted values (24 h) for the load and renewable energy sources.