2007년도 대한전기학회 전력기술부문회 추계학술대회 논문집 (2007. 11. 2 ~ 3)

게임이론을 이용한 MAS 기반 입찰모델링 기법 제안

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Game Theoretic Approach to MAS based Generation Bidding Model

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Abstract - MAS based market simulator has attracted the attentions of people who are interested in using or developing electricity market simulator. MAS based approach makes it possible to model each market participant's strategic behaviors. Traditional market simulators have used optimization formulation to model market operation, which has been used since vertically integrated system. Optimization mainly uses cost minimization or welfare maximization of entire system. Therefore it is somehow difficult to model the independently strategic behaviors of market participants. MAS is one of AI technology based on distributed intelligence which makes it possible to model independently acting entities in competitive market. This paper proposes the method to model strategic participants in electricity market based on MAS.

1. Introduction

Electricity market is quite complicated to be analyzed and forecasted because there are too many complexities. One of the complexities is incurred by different layers not existing in a similar dimension like the relation between physical system and abstract market architecture. The balance between supply and demand, system stability, load flow on transmission system are the primary requirements of physical dimension, while transactions in pool market and bilateral contract market are the secondary requirements in the facet of business area. Business contracts should be made only unless the contracts violate the constraints of the system to be stable and secure. There are two ways of modeling market simulators according to the approaches of handling the problem. One is the analytic method using the strict mathematical formulation with optimization techniques. The other is the empirical method based on trial and error concept using heuristic methods, for example genetic algorithm, tabu search, simulated annealing, and so on. We apply MAS (multi-agent system) based model to market simulation in this paper in lieu of traditional simulation method based on optimization formulation for modeling strategic interaction and dynamism of market participants, especially Gencos.

2. Traditional Market Simulators

Traditional simulators have applied the optimization formulation to market simulation. Linear programming has been preferred among many kinds of different optimization methods like linear programming, non-linear programming, combinatorial optimization, etc. because of its assurance on convergence and simplicity of modeling. Generally, generation cost minimization and social welfare maximization may be the objective functions of optimization problem. Physical capacities of generators and transmission lines are considered as the constraints of the optimization problem.

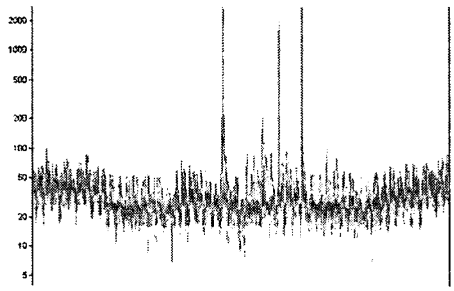

Fig. 1 Market Price Simulation

Optimization was a good method for the centralized resource planning and operation scheduling problem of vertically integrated utility in the electric power industry since there is only one decision maker which is the best case in considering the simulation as an optimization problem.

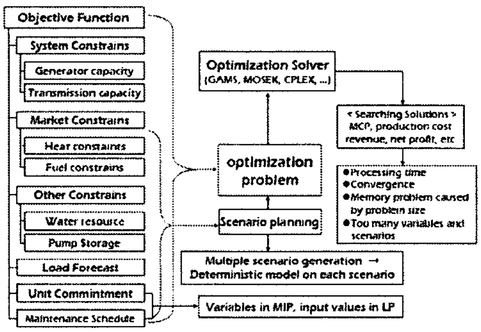

Fig. 2 Structure of traditional market simulator

But the formulation as one optimization problem of overall system or market tends to make the processing time longer and sometimes even shut down the computer by a critical memory problem due to the big problem size. Both PLEXOS of Drayton Analytics and CeMOS of CRA were created on the basis of the structure shown in Figure 2. Also, they adopt commercial optimization solvers like MOSEK and GAMS for solving the formulated optimization problem.

3 MAS based Market Simulator

3.1 Multi-agent system

The concept of "agent" has been introduced in artificial intelligence when we describe the program which performs some tasks specialized in some field or very complicated jobs to be done instead of a human. Multi-agent is a collection of more than one agent and has common characteristics like autonomy, social ability, intelligence, etc.

Autonomy means that agent can judge by itself and performs some tasks based on the judgement without the orders from humans or other programs. For example, if we apply agent technology to information search engine, then agents are able to collect, analyze, and arrange the information by itself even when there is no commands for searching from humans, while traditional information search engines do their job simply when they get orders.

Social ability means the agent's capability to cooperate with other agents to perform some tasks or accomplish some objects. Agent is not a stand-alone program but a member of society composed of a number of agents who cooperate with each other for the objective or a common good of the society. Each agent has its own unique role, and some agent has the role of coordinating the agent.

Intelligence means that agents perform tasks or accomplish objective according to their own reasoning and judging process not just based on codes or program already made by human, implying that agent can have the creativity or evolution on problem solving process.

3.2 Application of MAS to electricity market simulator

The MAS based market simulator could have multiple agents each of which is in charge of their unique roles for the operation of power system and electricity market. For instance, we can establish a society composed of multiple agents and define their relationships using the game theory.

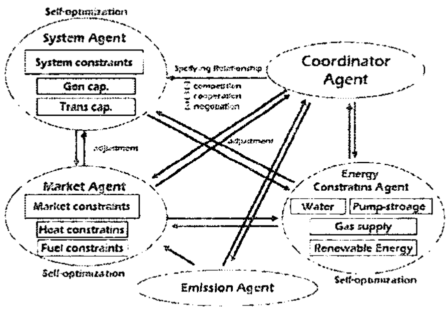

Fig. 3 Functional multi-agent composition

System agent is normally responsible for power system operation related to load flow and voltage stability subject to the generator installed capacity and transmission line capacity. Market agent tries to perform the market operation for the cost minimization and social welfare maximization under the heat constraints and fuel constraints. Energy constraint agent is obligated to manage limited energy resources like water flow, pump-storage, renewable energy sources.

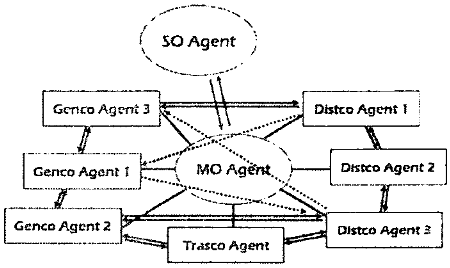

Fig. 4 Agent representing market participant

Agent may be also regarded as individual market participant like Genco, Transco, Distco, etc., which is the different aspect from the traditional market simulator having only one decision-making entity. Each agent represents each market participant having its own utility function and pursues the maximization of the utility function. Profit maximization can be another objective function of Gencos and Distco. Social welfare maximization may be the objective function of MO (market operator).

3.3 Game theoretic approach to MAS based market simulator

Relationship between agents is duly defined using game theo ry. Game theory provides us with three different kinds of g aming situation classified as cooperative game, non-cooperati ve game, and negotiation (or bargaining) game. In the same fashion, each game situation has a few sub-models like Cou rnot model, Bertrand model, Stackelberg game, Nash bargain ing game, etc.

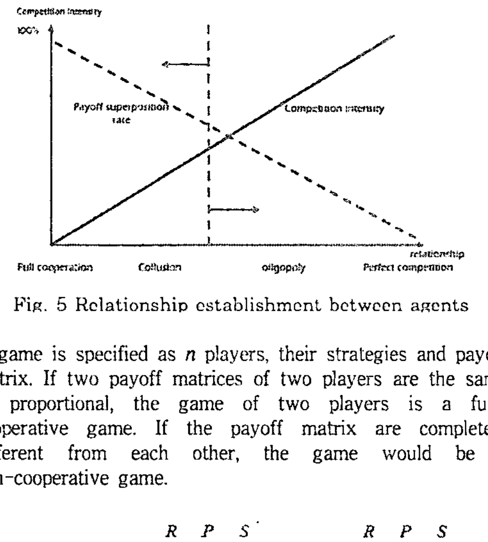

Fig. 5 Relationship establishment between agents

A game is specified as n players, their strategies and payoff matrix. If two payoff matrices of two players are the same or proportional, the game of two players is a fully cooperative game. If the payoff matrix are completely different from each other, the game would be a non-cooperative game.

A's action		R	P	S		R	P	S
	R	0	−1	+1	R	0	+1	−1
	P	+1	0	−1	P	−1	0	+1
	S	−1	+1	0	S	+1	−1	0
			A's payoff				B's payoff	

Fig. 6 Example for payoff matrices of two players

The strategic choice for the relationship between two agents is wholly determined by the judgement of agents. The choic es of agents may be different from each other even in same situation dependent on the objective function or the strategic preference of each agent.

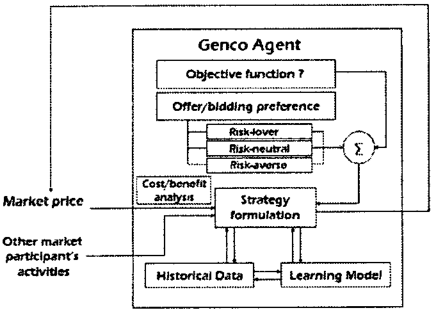

Fig. 7 Agent based Genco model

Each Genco has its own offer stack differentiated by its objective function and strategic preference. Genco more interested in market share than net profit will offer the lower price than expected marginal price, since it's priority lies in the increase of generation quantity supplied to the pool. Figure 8 shows the strategy to lower the offer price to raise the market share.

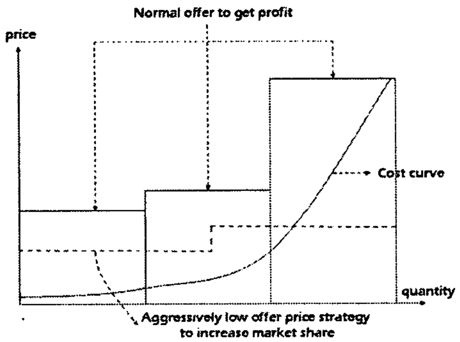

Fig. 8 Offer strategy change by objective function

Genco can choose the offer strategy as seen in Figure 9 if it prefers the risky strategy to pay back higher returns. If the Genco has the marginal generator, it will offer its generation with higher price than expected market price to raise the market clearing price. This is a typical phase of economic withholding in exercising market power.

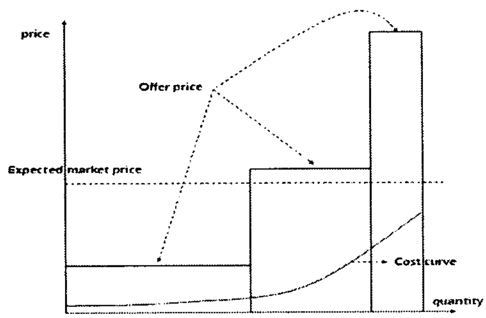

Fig. 9 High offer price strategy expecting higher return

Nevertheless the Genco should take a risk of being cut in its offer quantity partly or entirely, leading to the decreased net profit. Accordingly, the offer strategies of Gencos are influenced by their objective functions and strategic preference on offer or bid. The MAS based market simulator reflects these kinds of different tendencies and strategic evolutions based on intelligence or learning ability. And it makes the model more realistic in the fact that each Genco has its own decision making independency.

4. Conclusions

This paper has presented a basic concept of MAS based electricity market simulator and the theoretical framework for building it. Traditional market simulators focused on the mathematical formulation of an optimization problem and the algorithm for searching the solution. For mathematical formulation, the problem model was required to have a deterministic objective function and related constraints, which leads the model too deterministic and static. It has been of the highest importance to find out an optimal solution for investment on generators and transmission lines under vertically integrated environment since there is only one decision maker for the investment. Under the competitive market the equilibrium replaces the concept of an optimal point in the steady-state. And the dynamism of market also gets importance in that the market players always try to unbalance the equilibrium for increasing their profit while the market operator try to maintain it. Even if we find out the equilibrium of the market at a specific moment, it would be negligible by the reactions of market players within a short time-horizon and require a new equilibrium to be found. Capturing these characteristics of market environment, the emphasis of the MAS based simulator is on making the problem model itself more realistic as close as possible to the real situation rather than solving the problem and finding out the optimal solution. Although there is no obvious evidence which method is better for competitive market simulation, the MAS based market simulator is expected to overcome several weak points of traditional market simulators.

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