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Optimal bidding strategy for Hydrothermal scheduling in a Deregulated Energy Markets

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ABSTRACT

In the world-wide, the electricity power market has been unbundled from vertically integrated utilities to a deregulated electricity market. In this paper, the objective is to build an optimal bidding strategy for the GENCO for trading in perfect competition and oligopolistic market. The IEEE 30-bus test system is taken as the case study. The GENCO chooses its bid price coefficients for maximizing its profit in the deregulated market with the expected knowledge of bids of the rival's GENCO. A problem solution for optimizing the bidding coefficient of the GENCO has been carried out using Evolutionary Programming (EP). The numerical results obtained from the IEEE 30-bus shows the investigation of bidding strategies in the deregulated energy market.

Keywords: Bidding Strategies, Generating companies (GENCO), Deregulated Energy Market.

1. INTRODUCTION

The electricity power sector is globally changing operationally as well as in economic aspect from the vertical integrated model from generation to distribution is unbundled and has led to the introduction of private sectors. Thus the monopoly in power sector comes to an end. Initially the total process from generation to distribution is maintained by a single utility called vertically integrated utility. But the government allowed the private entities to invest and demand in the electricity power sectors. This becomes beneficial to both government and private sectors. But the government introduced regulations to control the private entities exploiting the end users.

Generally the market price in a deregulated electricity market ,distribution companies (DISCOs) submit their bids with the main aim of getting higher benefits, while generation companies (GENCOs) submit their bids with the aim of minimizing their costs (and consequently increasing their profits as well)[1]. Deregulation mainly focusses on the customer profit maximization. From another perspective, interpretations of this 'profit-based economic load dispatch' problem which deals with ensuring high profits through customer benefits [2]. Economic dispatch assigns system load demands to the many generating units with only aim of reducing power generation cost while unit commitment determines the unit start-up and shut down schedules, with the aim of minimizing system fuel expenditure[6]. The bids from the competitors are modelled by probability distributions. The generator data and load data is considered from [14]. The problem of building optimally coordinated bidding strategies for competitive suppliers in day-ahead energy and spinning reserve markets is addressed in [15]. Evolutionary Algorithms (EA) like EP have been used to solve many electric power systems problems, including electrical, economic dispatch problems, unit commitment problems, power operations, planning and scheduling of distribution systems, control of reactive power, etc. EAs tend to find good solutions in relatively time [7-10]. It is assumed that each supplier bids 24 linear energy supply functions and 24 linear spinning reserve supply functions, one for each hour, into the energy and spinning reserve markets, respectively. Here each

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market is cleared separately and simultaneously for all the 24 delivery hours. An interesting body of work has been carried out on developing bidding strategies for the GENCO and large consumers in emergent electricity markets in recent years, [16-18].

2. PROBLEM FORMULATION

2.1. Objective Function

The competitive electricity power market allows the energy trading between buyers (Consumers) and sellers (GENCO).It act as a centralized market.The sellers participating in trading are required to submit a bid of linear, non-decreasing energy function. After receiving energy bid functions from the sellers, the Power exchange (PX), matches the generation to meet out the demand in the day-ahead energy market.

An IEEE-30 bus test system is considered with six independent GENCOS or power suppliers providing the power generation to the group of consumers. This entire set up is monitored by a social beneficiary regulating body called Independent System Operator (ISO) in the PX market.

The bidding function of each GENCO is given by

$$BG_i\left(P_{in}\right) = a_{in} + \beta_{in} P_{in} \qquad n = 1, 2 \dots \dots T \tag{1}$$

Subject to

(i) Bidding constraint of the GENCO:

$$P_{in}^{\min} < P_{in} < P_{in}^{\max} \qquad n = 1, 2 \dots \dots T \tag{2}$$

(ii) Power balance of the GENCO:

$$\sum_{i=1}^{N} P_{in} = D_n \qquad n = 1, 2 \dots \dots T \tag{3}$$

Here α_{in}, β_{in} represent the bid price coefficient of the GENCO. P_{in} is the power generation of each GENCO which should between the minimum ($P_{in}^{\min}$) and maximum ($P_{in}^{\min}$) limits. D_n represents the power demand at time period 'n'.

The bids of the GENCO and demand bids are co-ordinated into a supply bid curve and demand curve respectively. Market Clearing Price (MCP) is the intersection point of the supply bid curve and demand curve. Therefore the MCP for each GENCO is calculated as

$$MCP_n = \left[D_n + \sum_{i=1}^{N} \alpha_{in} / \beta_{in}\right] / \sum_{i=1}^{N} 1/\beta_{in} \tag{4}$$

The power dispatch by each GENCO is expressed as follows:

$$P_{in} = \left(MCP_n - \alpha_{in}\right) / \beta_{in} \tag{5}$$

where$N$ is the total number of GENCO in a deregulated energy market.

Thus the objective of profit maximization of the GENCO is given by

$$\max(\text{Profit}) = \sum_{i=1}^{N} \sum_{n=1}^{T} \left[MCP_n . P_{in} - F_i\left(P_{in}\right)\right] X_{in} \tag{6}$$

Where $n = 1, 2 \dots \dots T$

3. EVOLUTIONARY PROGRAMMING

The approach carried out in this paper is to build into the EP in a candid way of familiarizing the search process to the search solution area, by training the mutation operation towards genes that are in the stage of the search are having negative influence on the cost function. Such 'smart' mutation has been used successfully in a variety of domains in which it is possible to relate components of the cost function to particular components of the genome.

An ordinal selection is performed where a selection decision is based on ranked order of the chromosomes' fitness values which is in this case the Market Clearing Price(MCP).

4. IMPLEMENTATION PROCEDURE:

The step-wise procedures for solving the bidding strategy in the deregulated energy market are:

Step 1: The bid price coefficients of the supplier GENCO and the power demands are specified.

Step 2**:** The bidding coefficient of the rival's GENCO is carried out using multivariate PDF as given below where l and k are distributed bivariate normal values.

$$= \frac{1}{2\pi\sigma_l\sigma_y\sqrt{1-\sigma^2}}\exp\left\{-\frac{1}{2\left(1-\sigma^2\right)}\left[\frac{\left(l-\mu_l\right)^2}{\sigma_l}+\frac{\left(k-\mu_y\right)^2}{\sigma_k}-\frac{2\rho\left(l-\mu_l\right)\left(k-k\right)}{\sigma_l\sigma_k}\right]\right\} \tag{7}$$

where E[l] = μ_l E[k]= μ_k SD(l) = σ_l SD(k) = $\sigma_k \rho$ $cor(l, k)$

This joint pdf gives the estimation of the bidding coefficient of the rival GENCOs and is expressed as

$$\left(l,k\right)\sim N\left\{\begin{bmatrix}\mu_l\\ \mu_y\end{bmatrix},\begin{bmatrix}\left(\sigma_l\right)^2 & \rho\sigma_l\sigma_y\\ \rho\sigma_l\sigma_k & \left(\sigma_k\right)^2\end{bmatrix}\right\} \tag{8}$$

The bidding coefficients of the rival are then calculated as

$$\left(\alpha_i^{(n)},\beta_i^{(n)}\right)\sim N\left\{\begin{bmatrix}\mu_{i,j}^{(\alpha)}\\ \mu_{i,j}^{(\beta)}\end{bmatrix},\begin{bmatrix}\left(\sigma_{i,j}^{(\alpha)}\right)^2 & \rho_{i,j}\sigma_{i,j}^{(\alpha)}\sigma_{i,j}^{(\beta)}\\ \rho_{i,j}\sigma_{i,j}^{(\alpha)}\sigma_{i,j}^{(\beta)} & \left(\sigma_{i,j}^{(\beta)}\right)^2\end{bmatrix}\right\} \tag{9}$$

Step 3: Evolutionary programming is used to optimize the bidding coefficient (β) of the Genco. Initial population is selected in such way that best result can be obtained within minimum time.

Step 4: The fitness function considered here is the MCP of the GENCO. By optimizing the bidding coefficient, calculate the power generation by using Equation (4).Check the values obtained are within the minimum and maximum limits.

Step 4: If the obtained power generation P_{in} is less than the minimum power generation limit the unit status *Xin* is*'OFF'* Otherwise the unit status X_{in} *is taken as 'ON'*.

Step 5: Knowing the units committed, the optimal power generations are obtained by performing economic load dispatch.

Step 6: The profit is then calculated from Equation (6)

5. RESULTS AND DISCUSSION

An IEEE 30-bus system is considered for trading in day-ahead market, considering it as six GENCOs over 24 hour load demand. To analyze the market behaviour under perfect and oligopolistic markets, it is taken that the GENCO-6 wishes to maximize its own profit when considered with other GENCOs-1 to 5 which are considered as rivals participating in the electric power trading.

5.1. Bidding parameters under Perfect competition

Here the bidding coefficients of all the GENCOS are taken equal to their cost respective coefficients participating for the entire trading period. Here the objective is to maximize the profit of GENCO-6 alone.

5.2. Bidding parameters under Oligopolistic competition

The bidding coefficients of GENCO-6 is used to calculate the MCP and the rival's GENCO (GENCOs-1 to 5 are considered as rivals) bidding coefficients from multivariate joint PDF. Here it is possible to obtain a good bidding strategy since the rival's bidding coefficient and thus their bidding behaviour are known. With the new MCP, the power transmit Pitis calculated from equation (3.5) and limit values are verified

In this case, the GENCO-6 is unable to supply the minimum power requirement during 1st, 2nd, 3rd and 5th hours. Thus the ON/OFF X_{it} status is obtained by considering the constraints to be satisfied in all trading periods.

5.3. Comparison of the results between perfect competition and oligopoly

The comparison results of revenue, cost and profits obtained under perfect competition and oligopolistic markets with and without optimizing bidding coefficients has been shown in Table 1. When the bid coefficient

Table 1
Comparison of profit under perfect competition and oligopolistic market

	Revenue($)	Cost($)	Profit($)
Perfect competition	6360.9579	5574.3163	786.6416
Oligopolistic market	7803.0045	5748.2489	2054.7556

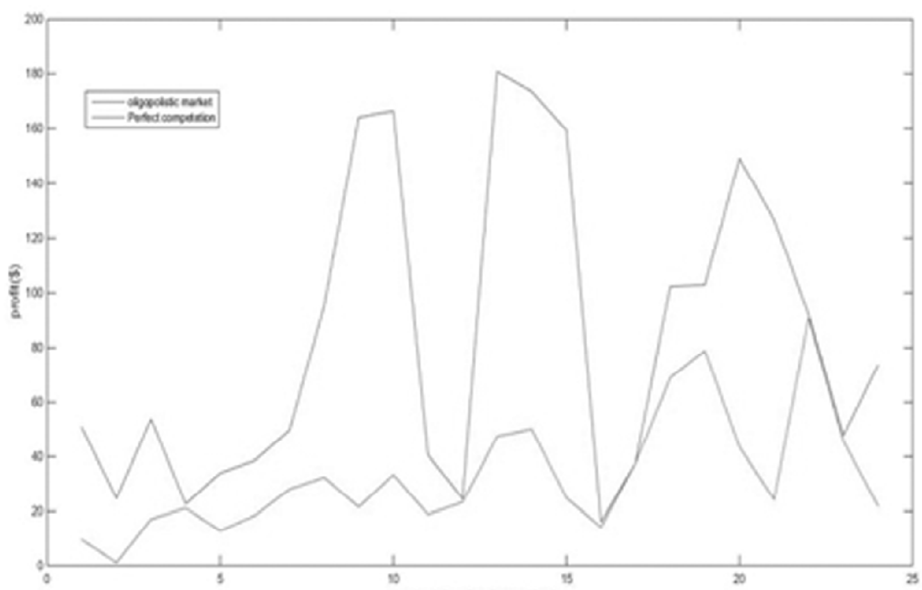

Figure 1: Comparison of MCP in perfect competition and oligopolistic market

β6 of GENCO-6 is optimized for all intervals, the profit obtained is $ 2054.7556 and when the bid coefficients are not optimized, the profit obtained is $786.6416. The cause for such increase in profit is that the algorithm performs repeatedly until maximum profit is attained. Figure1 shows the hourly variation of MCP under perfect competition and oligopoly markets.

It is found that profits obtained in oligopolistic market are high when compared with perfect competition. This is the due to the GENCO-6 submits the different bids in all intervals in oligopolistic market rather than taking the same bidding coefficients in perfect competition,

6. CONCLUSION

In this paper, a solution methodology has been proposed for solving optimal bidding strategy in perfect and oligopolistic market. Here the GENCOs bidding coefficient are optimized using EP. The comparative results in terms of profit maximization are presented in both perfect competition and under oligopolistic market. It is observed from the results that oligopolistic market yields higher profit when compared with perfect competition.

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