Bidding Strategy for Competitive Electricity Market by using Optimization Technique (PSO & APSO)

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***Abstract*— In an open competitive electricity market generators (supplier) and large consumer (buyer) need a suitable bidding model for enhancing their profits. Therefore, each generators (supplier) and large consumer (buyer) will bid strategically for the selection of bidding coefficients to check out the rivals bidding strategy. In this paper, bidding strategy problem is treated as an optimization problem and solved using Particle Swarm Optimization (PSO) and Adaptive Particle Swarm Optimization (APSO). PSO and APSO possess many similar characteristic with evolutionary computation techniques such as Genetic Algorithm (GA).**

First we have initialized The system with a population of random solutions and searches for optimal result in problem space by updating generation . In PSO, the potential solutions, known as particles, fly through the problem space in all direction by following the current optimum solution (particle). APSO is proposed to improve the performance of PSO (i.e. weight update technique is different in APSO and weight vary according to performance of particle). A numerical problem with six Generator (suppliers) and two large consumers (buyer) is used to describe the essential features of the proposed method. The results indicate that the APSO is better than PSO with respect to total profit.

Keywords*— *Prticle Swarm Optimization (PSO), Adaptive Prticle Swarm Optimization (APSO), Market Clearing Price (MCP), Bidding Strategy, Competitive Electricity Market.

I. INTRODUCTION

The Indian power market has change significantly over the past few years. This is mainly due to three factor- emergence of competitive bidding, growth of bilateral trading and introduction of power exchange. Around the world, the power system market is undergoing through restructuring process during the last decades . Before deregulation a traditional monopoly structure was exit in the power sector market. After deregulation process the Large consumer (buyers) and generators (suppliers) starts to interact regarding power transaction and maintain system security through system operator. Competitive electricity market consist of several Generating Companies, Transmission Companies and Distribution Companies along with the system operators.

The main aim of Restructuring the electricity market to abrogate old policy in the generation and trading sectors. It means introducing competition in electricity market at each and every possible levels. By this reform many issues are arise in the open electricity markets such as misuse of market power, profit orientated nature of the market, generating companies strategic bidding, price-demand relation and so on. According to Theoretical knowledge in a perfectly competitive open electricity market Generator (supplier) have a tendency to bid at their production cost to enhance profit. But practically due to profit orientated nature of electricity market, the generator (power suppliers) want to enhance their profit so they bid at higher price than production cost.

Bidding problem start here as generating companies know their production costs, technical parameter and behaviour of other bidder and electricity market behaviour, generators (suppliers) have to face the problem(i.e. how to get the best optimal bid). This problem is considered as a strategic bidding problem in electricity market. There are many approach to solve this problem but there are mainly three approach in which ample amount of work has been publish in various journal, first is by calculating market clearing price approach. Second is game theory approach and third is estimate the rival's bidding approach.

The main work of this paper is a new optimization technique known as Particle Swarm Optimization (PSO) [7] and Adaptive Particle Swarm Optimization (APSO) [13] are used to solve bidding strategy problem for generating companies and large consumers. The result indicate that the APSO is better optimization technique than PSO in terms of profit and it can give better optimized solution within short duration.

II.NEED OF BIDDING MODEL

After restructuring the electricity market the monopoly in generating sector is abolish. So now any generator (supplier) and large consumer (buyer) is free to sell or buy the electricity from anywhere. Bidding model is a platform which provide such transaction between supplier and buyer. In most of the country they have energy exchange in which this type of transaction is carried out. To participate in energy exchange,

supplier or buyer should have a bidding model which may be depend on past bidding history, rival bidding behaviour etc.
In India such transaction are carried out by IEX (Indian Energy Exchange). In this paper bidding problem is treated as an optimization problem. In competitive electricity market each generator (suppliers) and large consumer (buyer) want to increase their profit. For enhancing their profit they need a suitable bidding model in which they bid according to the rival bidding behaviour.

III. TYPE OF BIDDING

There are mainly four type of bidding exist in electricity market around the world. The classification of each is discuss below.

a. Multi-part Bidding

A multipart bid, is also known as complex bid. It may consist separate prices for ramps, start-up costs, shut-down costs, no-load operation, and energy [1]. This type of bid can be considered as ideal as it show accurate cost structure and technical parameter limit of generators (suppliers). The market clearing procedure is based on an optimization technique that optimize the winning bids. In this paper PSO & APSO is use as optimization technique for market clearing.This bidding leads to a centralization of the unit commitment decisions at the market operator's level, means market operator is decision taking body. All bidders are required to submit the relevant information and the market operator makes optimal decisions. The technical feasibility is guaranteed in this type of bidding. A very well-known example of the multipart bid is the England- Wales electricity market.

b. Single-Part Bidding

In this type of bidding, generators (suppliers) bid for only independent prices at each hour, and in this type of bidding market clearing mechanism is done as the winning bid is determined by the intersection point of supply bid curves and demand bid curves which is schedules for each hour. This approach is not centralized as in case of multi-part bidding. So this type of bidding is totally decentralized. In this case the market operator does not make unit commitment decisions. Hence, generators (suppliers) need to consider all involved costs and physical limit in constructing their bids for market. Since this type of bidding structure does not guarantee to redeem total cost. So this type of bidding does not guarantee feasibility. The single-part bid has been implemented in no of competitive electricity markets such as Australia California and Norway/Sweden [1].

c. Iterative Bidding

In this type of bidding generators (suppliers) and large consumer (buyer) are allow to change or modify their bid according to some rule [1]. But their costs must be appropriately allocated and their technical constraints considered. This method may have vast computational burden and may not be practical. There are some contradiction that a single bid is not sufficient mechanism for market to run efficiently, and then introduce a new technique known as asynchronous iterative bidding scheme. The difference between these two iterative method is a feedback. It works such that when it receiving generation levels from the first-round of market clearing, generators (suppliers) are allowed to change or modify their bids one more time if they want. The optimal bidding problem is solved based on this bidding scheme, and a radial basis function neural network is used for this purpose.

d. Demand Side Bidding

There are many electricity markets around the world such as California, New Zealand and Spain, demand side bidding is start and used only for large consumers to react to electricity pricing. Earlier only generating unit are allowed to determine the price of electricity but, on introducing demand side bidding In the market that leads to maximization of social welfare. Now this approach should be employed for bid clearing, and the market using minimum price approach with supply side bidding is no longer exist and that is not fair to the sellers. To maximize the social welfare in this case both the generators(sellers) and large consumer (buyers) are bidders, and the buyers are no longer passive in this scheme. Earlier the demand side bidding was not permitted, the minimum price approach was employed and in this case the large consumer (buyers) are passive and their profit was protected by regulations. Till today research work on strategic bidding is focused on the supply side, bur now may electricity market start this scheme due to its impact on social welfare and profit.

IV. Bidding Scenario In India

Power exchanges in India was commence in 2008. There was a need for a market place in India, where large consumer (buyers) and generators (sellers) could meet and buy or sell power with genuine price discovery. The motivation for establishing such market place in India comes from the Electricity Act, 2003, which is the first act to introduced the concept of non-discriminatory open access for power through rules and regulation for promoting competition in the electricity market. As the major step taken by the Electricity Act, 2003 the country's power markets have been witnessing significant innovation. Further efforts are positive regulatory that create a competitive market and supported by the efforts of market operators to introduce new products and solutions that benefit consumers, suppliers and the power sector as a whole. Before the functioning of power exchanges in India, an alternatives method was used for purchasing short-term power that consist the unscheduled interchange (UI) market (where prices were volatile) and over the-counter (OTC) trading mechanisms (which typically have high transaction costs). Only the OTC mechanisms continue to serve an important function, earlier consumers wanted a platform that allowed them to enter standardized contracts, take care of counterparty risks, and provided fixed acceptable future electricity price signals. The customer demand for such contracts led to the evolution of power exchanges in India.

At present, the power exchanges of India account for 30 per cent of the power transacted in the short-term market, so serving as a valuable link in bridging the power demand-supply gap. The IEX is the leading energy trading platform of India with a 90 per cent market share. Earlier it started operations with a few of participants. But at present, the number of participants on the exchange has increased to 2,600, comprising 27 states, five union territories and 500 generators. Of these, over 2,000 are industrial consumers.

The IEX provides a platform for trading power in two type of market first is the day-ahead market (DAM) and second is the term-ahead market (TAM). IEX also start operation in near future for the renewable energy segment.

V. Problem Formulation

The numerical problem which we have taken for understanding of the real bidding environment in the electricity market is define here. Suppose a electrical system consist of 'm' no of Generators (suppliers) and an inter connected network maintained by an Independent System Operator (ISO), a Power Exchange (PX), total consumer load which does not participate in demand-side bidding in electricity market but it is elastic to the price of electricity, and there are 'n' large consumers (buyers) who participate in demand-side bidding. PX define the range in which generators (supplier) and large consumer (buyers) will bid. The bidding is done as, the generators (supplier) and large consumer (buyers) will bid in a linear non decreasing supply function and non increasing demand function.

Linear supply curve for bidding of a generators is denoted as

Gi(Pi)=ai+biPi where i=1..m

Linear demand curve for bidding of a large consumer is denoted as

Wj(L)=cj-djLj where j=1...n

In above equation Pi is the active power output of generators, ai and bi are the supply bidding coefficients of the ith supplier. Lj is the active power load of large consumer, cj and dj are the demand bidding coefficients of the jth large consumer. Supply and demand bidding coefficient (ai, bi ,cj and dj) are positive. The function of PX is to calculate the Pi/Lj which must be within the limit of system operating parameter and that must be meets security parameter of the system. This leads to maximum profit and social welfare. It is observed from many electricity market that when the generators (suppliers) and large consumers (buyers) bid in the linear supply function and linear demand functions and the system parameter are ignored, then enhancing profits leads to a uniform market clearing price for all participant. Now, when only the load flow limit and generators (suppliers) output limit and large consumers (buyers) demand limit are taken into account then PX will determines a set of generators (supplier) outputs P = (P1,P2,P3…Pm)T and a set of large consumers (buyers) demands L = (L1,L2,L3….Ln)T by solving equations (1) to (5) shown below.

$$ai + biPi = R \quad i = 1,2 \ldots m \qquad (1)$$

$$cj - djLj = R \quad j = 1,2 \ldots n \qquad (2)$$

$$\sum_{i=1}^{m} Pi = Q(R) + \sum_{j=1}^{n} Lj \qquad (3)$$

$$Pmin,i \leq Pi \leq Pmax,i \quad i = 1,2 \ldots m \quad (4)$$

$$Lmin,j \leq Lj \leq Lmax,j \quad j = 1,2 \ldots n \quad (5)$$

Where R is the uniform market clearing price of electricity to be determined and Q(R) is the aggregate pool load forecast by PX and this information made public for all participants and is considered as it will be elastic to the price of electricity in the market. Here Pmax and Pmin are the generators (suppliers) output limits of the ith supplier, and Lmax and Lmin are the demand limits of the jth large consumer (buyers). The mathematical formula for Q(R) is define below and equations (1) to (3) can be solved directly. Assume that the aggregate pool load Q(R) follow the linear form shown below.

$$Q(R) = Qo - KR \qquad (6)$$

In the above equation Qo is a constant number and K is a positive coefficient that show price elasticity of the aggregate demand (i.e. depend on the price of electricity). If pool demand does not depend on price of electricity, then K=0. The condition given in equation (4) and (5) are ignored, the solutions to equations (1) to (3) are given below.

$$R = \frac{Qo + \sum_{i=1}^{m}\frac{ai}{bi} + \sum_{j=1}^{n}\frac{cj}{dj}}{K + \sum_{i=1}^{m}\frac{1}{bi} + \sum_{j=1}^{n}\frac{1}{dj}} \qquad (7)$$

$$Pi = (R-ai)/bi \qquad i=1,2\ldots m \qquad (8)$$

$$Lj = (cj-R)/dj \qquad j=1,2\ldots n \qquad (9)$$

When the equation (8) and (9) violates generators output limit (4) and consumer demand limits (5) then it must be rearrange according to given limits. Let the ith generator follow a cost function define as $Ci(Pi) = eiPi + fiPi$ where ei and fi are cost function coefficients. For enhancing the profit of generator a bidding strategy is adopted, which is shown below.

Maximize F(ai,bi)=RPi-Ci(Pi)

This equation is subjected to equation (1) to (5). This equation is modified by putting the value of cost function as.

$$F(ai,bi) = (ai - bi)Pi + (bi - fi)Pi^2 \qquad (10)$$

The main objective to calculate ai and bi so as to enhancing the profit F(ai,bi) with the help of equation (1) to (5). Ci(Pi) is the production cost function of the ith generators (suppliers). Now the ith large consumer (buyers) follow a revenue function define as $Bj(Lj) = gjLj - hjLj$, here gj and hj are the demand function coefficients. For enhancing the profit of generator a bidding strategy is adopted, which is shown below.

$$Maximize\ B(cj,dj) = Bj(Lj) - RLj$$

This equation is subjected to equation (1) to (5). This equation is modified by putting the value of revenue function as.

$$F(cj,dj) = (gj - cj)Lj - (hj - dj)Lj^2 \quad (11)$$

In the competitive electricity market sealed based auction method is adopted. In this method bidding data for the next time is confidential. So this is the problem for generators (suppliers) and large consumers (buyers) to solve the equation (10) and (11). But the past bidding data is available, and this data made public for all participant, so they can make use of this information for bidding problem. But the next problem for each participant is to forecast the bidding coefficients of rivals (large consumers). Let assume that the ith generators (supplier's) has forecast that rival's jth (j ≠ i) bidding coefficients follow a joint normal distribution function with the following probability density function (PDF). The probability density function (PDF) is define below.

$$PDFi\ (aj, bj) = \frac{1}{2 \times \pi \times \sigma_j^{(a)} \times \sigma_j^{(b)} \times \sqrt{1-\rho j^2}} \times exp\left[-\frac{1}{2\times(1-\rho j^2)}\left[\left(\frac{aj-\mu_j^{(a)}}{\sigma_j^{(a)}}\right)^2 - \frac{2\times\rho j\times\left(aj-\mu_j^{(a)}\right)\times\left(bj-\mu_j^{(b)}\right)}{\sigma_j^{(a)}\times\sigma_j^{(b)}} + \left(\frac{bj-\mu_j^{(b)}}{\sigma_j^{(b)}}\right)^2\right]\right] \qquad (12)$$

Where ρj = correlation coefficient between ai and bi..

μj(a), μj(b) = mean value (Parameter of joint normal distribution).

σj(a), σj(b)= standard deviation (Parameter of joint normal distribution).

Same probability density function (PDF) can be written for large consumers also. Which will be used for finding the bidding coefficient of large consumers. Now with probability density function (PDF) and equation (10) & (11) subjected to condition given in equation (1) to (5) becomes a stochastic optimization problem. That is solve with the help of optimization technique. In this paper I am using PSO & APSO for solving this stochastic problem.

VI. Particle Swarm Optimization (PSO)

The PSO technique is an un-supervise optimization technique that is based on social interaction such as bird flocking and fish school. This technique is suitable for any nonlinear or random optimization problem. It was first discovered in 1995 by a social psychologist James Kennedy and an electrical engineer Russell Eberhart [7]. The basic concept of PSO is that, the optimized result obtained is called as particles and the particle try to fly through the problem space in N dimension by tracking the best optimal result so far of the particles. It has some basic similarity with the available computation techniques in the market such as initialization. In PSO initialization is done as, first a mass of random solution is taken and then search for optimal solution by updating the particle weight. In PSO each particle is considered just as a point in a N-dimensional problem space. This point adapt its flying according to its own flying experience as well as the flying experience of other neighboring particles in problem space. Equation (13) written below is used for updating the velocity, at each iteration a modified velocity is obtained for each particle based on its previous velocity (Vr k), the particle's location at which the best fitness has been calculated (Pbest r) so far, and the best particle among the neighbors (Gbest r) at which the best fitness has been calculated so far. The learning factors C1 and C2 are the acceleration constants that change the velocity of a particle towards (Pbest k) and (Gbest k), and rand1, rand2 are uniformly distributed random numbers in [0, 1]. Each particle's position is updated using equation (14) in the solution space. The velocity is update by using equation (15).

$$V_r^{k+1} = W^k \times V_r^k + C1 \times rand1 \times \left(P_{best}^k - X_r^k\right) + C2 \times rand2 \times \left(G_{best}^k - X_r^k\right) \qquad (13)$$

$$X_r^{k+1} = X_r^k + V_r^{k+1} \qquad (14)$$

$$W^k = W_{max} - \frac{W_{max-W_{min}}}{K_{max}} \times K \qquad (15)$$

Where Vr k: It is the velocity of particle r at iteration k

Wk: Weight at kth iteration.

C1, C2 : Acceleration factor.

rand1, rand2: uniformly distributed random number between 0 and 1.

Xr k : current position of particle r at iteration k.

Pbest k : Best fitness of particle at kth iteration.

Gbest k: Best fitness of group at kthiteration.

Xr k+1: New position of particle.

Wmax: Maximum weight.

Wmin: Minimum weight.

Kmax: Maximum Iteration.

K: Iteration.

The velocity update equation (13) have three term and all have their own significance in updating velocity. The significance of first term which contain inertia is that, it will continue to fly the particle in the same direction until it get first result. Therefore we can say first term is responsible for exploring new areas in problem space. If first term is not part of velocity update equation then the velocity of the particle is only calculated by current position and best position in history. So the first term is very essential to get optimal solution. The second term representing memory and third term representing cooperation. All three term together try to converge the particles to their (Pbest k) and (Gbest k) in the search procedure

A. PSO Algorithm for Bidding Problem

It is observe that for maximizing the profit of a generators (suppliers) or large consumer (buyers), The coefficients of both member (ai,bi) and (cj,dj) cannot be selected independently. So the solution for this is a generators (suppliers) or large consumer (buyers) can fix any two coefficients and then determine the other two by using an optimization procedure. In this paper PSO is applied to find the optimal bidding coefficients and profit of each participant. Here PSO is used for two purpose and the algorithm is describe below[7].

1. PSO for obtaining optimal bidding coefficients (bi/dj).

Step1. Initialization of the particles

(a) Initialize randomly the population of bi solutions in a matrix form. where bi is the bidding parameter of the ith generators (suppliers) to be optimized.

(b) Read input data μ ,σ , ρ,ai and maximum iterations. where μ = mean , σ =standard deviation, ρ =correlation coefficient of probability density function (PDF) , ai= cost coefficient of generators.

Step2. Calculate the fitness evaluation function for each individual bi, by the equation (12). Here probability density function (PDF) is Fitness evaluation.

Step3. Now each Pbest values are compared with the other Pbest values in the population. The best value among the Pbest is replace as Gbest.

Step4. Now update the velocity V by velocity update equation (13) of each individual bi

Step5. Now update the position by position update equation (14) of each individual bi.

Step6. Now repeat the step from 2-5 until iteration reaches their maximum count. Return the best optimal value of bi. At final iteration the value bi is considered as a global solution. By Using the values bi, find out MCP from equation (7).

A similar algorithm is used for the estimation of the optimal values of dj.

2. Maximization of profit for supply-side biding using PSO.

Step1. Initialization of the particles

(a) initialize randomly population of power Pi solutions where Pi is the power of the ith supplier.

(b). Read input data of Generators (i.e. cost coefficients, Pmax, Pmin), demand (Q0) and maximum number of iterations.

Step2. Calculate the Fitness evaluation function by using equation (10) and (11).

Step3. Now each Pbest values are compared with the other Pbest values in the population. The best evaluation value among the Pbest is replace as Gbest.

Step4. Now update the velocity V by velocity update equation (13) of each individual Pi.

Step5. Now update the position by position update equation (14) of each individual Pi.

Step6. Repeat from steps 3- 5 until iteration reaches their maximum count. Return the best fitness value of power within the given limit and maximum profit.

At final iteration both value considered as global solution.

PSO uses random initialization, but it gives almost the same optimal solution in a set of simulations within a given case. It shows its immunity to the start point. In PSO weight is update after every iteration that is known as Inertia Weighted Approach (IWA). At starting weight is define as maximum weight and minimum weight. By Linearly Decreasing (LD), the inertia weight change from large value t small value during PSO code run. The PSO tends to have more global search ability at the starting of the run while having more local search ability near the end of the run. Hence, IWA provides a balance between global and local search. Maximum iterations required to obtain the global solution and it is dependent on the nature and the size of the problem.

B. Adaptive Particle Swarm Optimization (APSO)

This is the further modification in the conventional PSO. As both are optimization technique and learn from the surrounding particles, but APSO [13] is little advance in the search for optimal solution. In conventional PSO algorithm, non optimal particles have a tendency to shift near the location of Gbest. Therefore, the global optimal particle must explore new areas and update the Gbest to give momentum to the search of other particles. In this optimization technique an adaptive PSO algorithm is proposed to improve its performance. In this approach Different particles are allocated with different tasks. As in case of conventional PSO, we define weight at starting with maximum weight and minimum weight. But in this technique we can vary the weight according to the performance or task of particles. The particles with better performance have larger inertia weight, which allocate the task of searching better area. The particles which have poor performance are assign by a smaller inertia, allowing them to quickly converge to a better area for detailed search. By the variation in weight a large inertia weight is responsible for a global search while a small inertia weigh responsible for a local search. The particles are arrange in order of their individual optimal location from excellent to worst. The weight update formula for APSO is describe below. In this technique acceleration constant also update after every iteration, the update formula is describe below.

$$Wi=Wmin+(Wmax-Wmin)\times((m-i))/((m-1)) \quad (16)$$

$$Ci1=Ci2= (Wi+1+2\times\sqrt{Wi})/2 \quad (17)$$

Where m is define in above equation as population size, inertia weigh Wi is adjusted according to the above equation. By this technique both global and local search can be done in each iteration step. In APSO velocity and position will be update same as in case of PSO, but weight and acceleration factor will be update according to equation (16) & (17).

1. APSO for obtaining optimal bidding coefficients (bi/dj).

For APSO first five step will be same as PSO and two additional step is written below.

Step6. Update the weight Wi for each individual bi is according to the weight update equation (16).

Step7. Update the acceleration factor Ci1,Ci2 for each individual bi is according to the acceleration factor update equation (17).

Step8. Repeat from steps 3-7 until iteration reaches their maximum count. Return the best optimal value of bi. At final iteration as a global fitness. Using bi values, calculate MCP from equation (7).

A similar algorithm is applied to find the optimal values of dj.

2. Maximization of profit for supply-side biding using APSO

For APSO first five step will be same as PSO and two additional step is written below.

Step6. Update the weight Wi for each individual bi is according to the weight update equation (16).

Step7. Update the acceleration factor Ci1,Ci2 for each individual bi is according to the acceleration factor update equation (17).

Step8. Repeat from steps 3- 7 until iteration reaches their maximum count. Return the best fitness value of power within the given limit and maximum profit.

At final iteration both value considered as global solution. APSO gives the more global solution than PSO, as at every iteration the weight and acceleration factor is updating according to equation (16) & (17). It will search more optimal solution as at starting some of the particle have different weight and after first iteration weight is assigned according to performance. So search start from poor performance and end at better performance.

VII. Result And Discussion

As we have consider there are six generators (suppliers) and two large consumer (buyers). The data for Generators and large consumer is given in the Table 1. The value of some mathematical coefficient used in bidding problem is also given as Qo(a constant number) is 300 and K (coefficient denoting the price elasticity of the total demand) is 5. In this paper, the other parameters related to PSO/APSO are used after fine tuning are, Population size: 50, accelerating factors (for PSO only), C1=C2=2.0, inertia weight W (Wmax,Wmin): 1.0 to 0.5, Maximum number of iterations: 150. Simulations are carried on 1.80GHz, Intel(R) core(TM) i5-3337U Processor, 6GB RAM and MATLAB R2010 version is used.

Table1. Generator and Large Consumer Data

Generator No.	E	F	Pmin(MW)	Pmax(MW)
1	6	0.01125	40	160
2	5.25	0.0525	30	130
3	3	0.1375	20	90
4	9.75	0.02532	20	120
5	9	0.075	20	100
6	9	0.075	20	100

Large consumer	g	H	Lmin(MW)	Lmax(MW)
1	30	0.04	0	200
2	25	0.03	0	150

e : Cost function coefficient of ith generator.

f : Cost function coefficient of ith generator.

g : Demand function coefficient of ith generator.

h : Demand function coefficient of ith generator.

Pmin(MW),Pmax(MW) : Generator limit.

Lmin(MW),Lmax(MW) : Demand limit.

VIII. With symmetrical information

There are two case in bidding strategy. In first case all the participant have same information about the past bidding history or we can say each participant have same estimation. But in second case some participant make better estimates than other. In my paper I am considering first case that all six generators (suppliers) and two large consumer (buyers) have same information and same estimation. In electricity market each rival participant is assumed to have an estimated joint normal distribution for the two bidding coefficients. Let assume the joint normal distribution parameter that are described in PDF equation (12) are define as.

$$\mu i(a)=1.2\times ei \qquad \mu i(b)=1.2\times 2\times fi$$

$$4\times\sigma i(a)=0.15\times ei \qquad 4\times\sigma i(b)=0.15\times fi \qquad \rho i=-0.1 \quad (18)$$

$$\mu j(c)=1.2\times gj \qquad \mu j(d)=1.2\times 2\times hj$$

$$4\times\sigma j(c)=0.15\times ej \qquad 4\times\sigma j(d)=0.15\times fj \qquad \gamma j=0.1 \quad (19)$$

Where ρi = correlation coefficient between aj and bj.

μi(a), μi(b) = mean value (Parameter of joint normal distribution).

σi(a), σi(b) =standard deviation (Parameter of joint normal distribution).

A reasonable explanation is not available for the equation (18) and (19). It must be solved with the help of mathematical assumption. But these equation show a distinct pattern which is available in past bidding history. So we can say these equation are the estimation of past bidding data available for all participant. these parameters are just to show the basic feature of the method and these equation may not fully reflect the practical situations. It is a reasonable assumption about these equation that a generators (suppliers) who know the condition of power market from past history, so want to increase its profit by bid above the production cost (marginal cost). Hence, the expected values of ai and bi (i.e. value of mean value μj(a),μj(b) are specified 20% higher than ei and 2×fi respectively. The standard deviations of ai and bi , (i. e. σj(a),σj(b) are specified to make ai and bi fall in the range of [1.05× ei, 1.35 ×ei] with probability of 0.9999. ρi is specified to be negative because it show inverse relation with bidding coefficient means when a generators (supplier) increase one of his bidding coefficients, it is more likely that, in a power market, it will decrease rather than increase the other coefficient.

A similar explanation is applicable for the parameters in equation (19). In this paper by using PSO, bidding coefficients of generators (suppliers) and large consumer (buyers), generators outputs, market clearing price(MCP) and profit of six generators (suppliers) and two large consumers (buyers) are calculated. The same problem is also solved by using APSO and compared with PSO as shown in Table 2 and Table 3. Table 2 shows the optimal bidding coefficient of generators and large consumers and Table 3 shows the MCP and profit of each generators (supplier) and large consumers. From the Table 3, it is observed that the profits obtained by each generators (supplier) is more, when compared with PSO, therefore the bidding strategies obtained by APSO is better than PSO. The major difference between APSO and PSO is that, in APSO, the weight and acceleration factor are define on the basis of performance of particle and weight is update after every iteration which leads to better optimal solution. The simulation result shows that the APSO is more efficient optimization technique than PSO.

Table 2. Bidding Strategies of Generators and Consumers

	APSO	PSO
Generators no.	**bi**	**Bi**
1	0.081	0.057
2	0.077	0.069
3	0.259	0.245
4	0.057	0.053
5	0.165	0.104
6	0.165	0.125
Large consumer no.	**dj**	**Dj**
1	0.083	0.082
2	0.056	0.051

Table 3. Bid Price ($/MWh) and Profit ($) of Generators and consumers

	APSO		**PSO**	
Generator no.	**P (MW)**	**Profit**	**P (MW)**	**Profit**
1	139.25	1440.3	158.66	1253.53
2	97.65	505.48	107.53	482.50
3	41.31	277.03	40.61	247.49
4	105.94	470.00	108.71	438.87
5	46.11	251.64	51.60	144.04
6	46.11	251.64	51.60	198.62
Large consumer no.	**L (MW)**	**Profit**	**L (MW)**	**Profit**
1	164.13	1400.9	157.97	1278.60
2	143.86	792.34	140.53	667.21
MCP	17.62		15.89	
Total Profit	7883.12		4710.88	

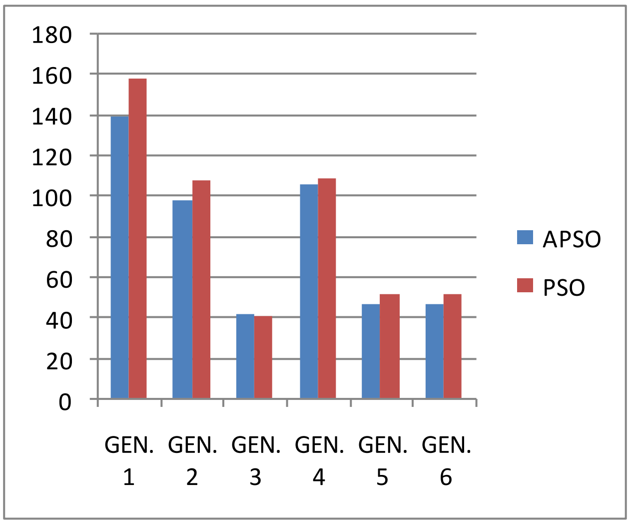

Figure 1 Expected dispatched powers of generators

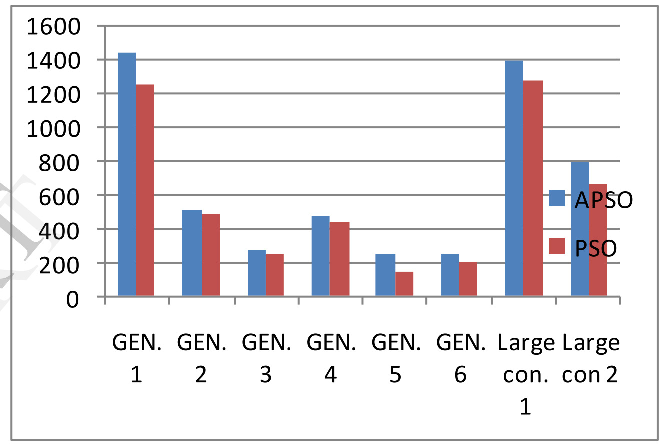

Figure 2 Expected profits vs Participant of suppliers and consumers

The superiority of the APSO approach is demonstrated through comparison of simulation results with PSO. These are the optimization technique based on random initialization. So because of their random nature, their performance cannot be judged by the result of a single run of MATLAB code, means we cannot get optimal solution in the first run of MATLAB code. In this paper to get optimal solution many trails with different initializations were made to reach a valid conclusion about the performance of the algorithms. An algorithm is robust, if it can guarantee an acceptable performance level under different conditions. Since APSO and PSO are random in nature therefore the bidding data was executed 20 times for all the approaches. After executing bidding data more than 20 times, the optimal result is shown above.

IX. CONCLUSION

In this paper optimization techniques are use to solve the random bidding problem. APSO and PSO are the two optimization technique which we have used for bidding problem in this paper. In the competitive electricity market every participant want to increase its profit by using information announced by market operator. Here we have discuss about the symmetrical information of rival in electricity market, that information is also random in nature , to utilized these information we have used APSO and PSO. Advantage of APSO and PSO with other optimization technique is that, it depend on only one operator and its ability to control convergence. But APSO gives more optimal solution than PSO as in APSO weight and acceleration factor are updating after every iteration, that leads to searching of better optimal solution. In this paper, these advantages of APSO are also confirmed with the simulation results.

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