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Congestion Management in an Electricity Market using Catfish PSO

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***Abstract*—In a deregulated electricity marketcongestion management of the transmission network is an essential task of an Independent System Operator (ISO).A congested transmission network threatens the safe and secure operation of a power system and reduces the competitiveness and efficiency of the electricity market. In this paper, an OPF based congestion management procedure has been discussed and Catfish Particle Swarm Optimization (C-PSO) has been utilized to manage the congestion. The proposed C-PSO based algorithm has been implemented on an IEEE 30-bus system and compared with the basic PSO based algorithm. The results have shown that the C-PSO based congestion management gives better results as compared to PSO based congestion management.**

***Keywords*—Congestion management, Optimal Power Flow, Particle Swarm Optimization,Catfish PSO.**

I. Introduction

The privatization and deregulation of the electricity industry has brought huge shifts in the planning, operations and management of a power system. The introduction of competitiveness in the market did not only bring benefits, but also made the industry to face unprecedented issues. Unlike the other markets, the competitive electricity market has salient characteristics, which make its operation a major challenge. Some of the complexities with electricity market are the lack of major storage capability, the just-in-time manufacturing nature of electricity and the limited capacity of the transmission and distribution networks. As the number of market participants increases the number of desired transactions between the various participants also increases, which gives rise to the congestion of transmission network. One of the key requirements for the proper functioning of electricity markets is an effective management of congestion.

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Several studies are done on the impacts of congestion and different transmission and congestion management (CM) approaches. Christie et al. [1] have described the various methods of congestion management used in different electricity markets. Ashwani Kumar et al. [2] have extensively reviewed literature reporting several techniques of congestion management.Song et al. [3] have proposed a model in which the system stability is incorporated into the congestion management, and the concept of market-based congestion management is extended into the dynamic scenario.Kennedy and Eberhart. [4] have described the particle swarm optimization concept in terms of its precursors, briefly reviewing the stages of its development from social simulation to optimizer.Chen et al. [5] used PSO for solving Optimal Power Flow (OPF), which is used for congestion management in a pool electricity market; they have also shown that congestion management using PSO based approach is more effective as compared to the Genetic Algorithm approach.

This paper focuses on the ability of C-PSO based algorithm to solve the problem of congestion management by optimal scheduling of generators on the basis of their bids submitted in a pool electricity market. Subsequently, the algorithm is compared with PSO based algorithm on an IEEE 30-bus system.

II. Optimization Techniques

A. *Particle Swarm Optimization (PSO)*

Particle swarm optimization is a stochastic, population-based search and optimization algorithm. James Kennedy and Russell C. Eberhart first described the particle swarm optimization algorithm in 1995[4], motivated by the social behavior of organisms such as flock of birds and school of fishes. Its basic idea came from the research on the social behavior of birds flock. A flock of birds search for the food in a stochastic manner, they search the area around the bird which is presently closest to food and increases their probability of getting food.

The basic unit of a PSO algorithm is a particle, which presents a potential solution in D-dimensional space. The particles and randomly generated in the search space with two attributes i.e. position (X_i) and velocity (V_i).The fitness value of each particle is evaluated at every iteration and all particles keep a track of individual best(*pbest*) and global best(*gbest*) position to adjust their own position and velocity in subsequent iterations. The particle velocity and position are updated according to following equations.

$$V_i^{k+1} = wV_i^k + c_1 r_1 \left(pbest_i^k - X_{id}^k \right) + c_2 r_2 \left(gbest^k - X_i^k \right) \quad (1)$$

$$X_i^{k+1} = X_i^k + V_i^{k+1} \quad (2)$$

Where r_1 and r_2 are random values between 0 and 1;w is the inertia weight;c_1 and c_2 are the acceleration constants; k is the iteration number.

B. *Catfish Particle Swarm Optimization (C-PSO)*

The motivation for the development of CatfishPSO was derived from the observation of the catfish effect i.e. when catfish were introduced into large holding tanks of sardines [6], the catfish competition with sardines stimulate a fresh movement amongst the sardines. Similarly, when the catfish particles are introduced, they stimulate a renewed search by the sardine particles in Catfish PSO. The catfish particles can guide the particles trapped in a local optimum on to a new region of the search space, and thus to potentially better solutions.

In CatfishPSO, a population is randomly initialized similar to PSO; the particles are distributed over the entire D-dimensional search space. The position and velocity of each particle are updated by using (1-2). The dynamically updating inertia weight w is calculated according to following equation

$$w = w_{\max} - \frac{w_{\max} - w_{\min}}{iter_{\max}} \times iter \quad (3)$$

If the distance between *gbest*and the surrounding particles is small, each particle in the cluster around *gbest*will only move a very small distance in the next generation. To avoid this premature convergence, catfish particles are introduced and replace the 10% of original particles with the worst fitness values of the swarm. These catfish particles are important for the success of a given optimization task. Further details on CatfishPSO mechanisms can be found in Chuang et al. [6].

III. Congestion Management Formulation

The objective of congestion management is to commit to such a schedule which will minimize the cost of active power purchased by the pool and at the same time maintain system reliability and security. On the basis of the supply side (generator) bids the optimal schedule is generated by solving the following optimization problem.

$$Minimize \sum_{i=1}^{N} C_i(P_{gi}) \quad (4)$$

Subjected to

Equality Constraints: These are the sets of nonlinear power flow equations t i.e.

$$P_{gi} - P_{di} - \sum_{j=1}^{n} |V_i|.|V_j|.|Y_{ij}|\cos(\theta_{ij} - \delta_i + \delta_j) = 0 \quad (5)$$

$$Q_{gi} - Q_{di} - \sum_{j=1}^{n} |V_i|.|V_j|.|Y_{ij}|\sin(\theta_{ij} - \delta_i + \delta_j) = 0 \quad (6)$$

where $P_{gi}$and $Q_{gi}$are the real and reactive power outputs injected at bus $i$respectively, the load demand at the same bus is represented by $P_{di}$and Q_{di} , and elements of the bus admittance matrix are represented by $|Y_{ij}|$ and θ_{ij} .

Inequality Constraints:

1) The generators real and reactive power outputs

$$P_{gi}^{\min} \le P_{gi} \le P_{gi}^{\max} \quad i = 1, \cdots, N \quad (5)$$

$$Q_{gi}^{\min} \le Q_{gi} \le Q_{gi}^{\max} \quad i = 1, \cdots, N \quad (6)$$

2) Voltage magnitudes at each bus in the network

$$V_i^{\min} \le V_i \le V_i^{\max} \quad i = 1, \cdots, n \quad (7)$$

3) The MVA loading of the transmission lines

$$MVA_{ij} \le MVA_{ij}^{\max} \quad (8)$$

IV. Solution using PSO and C-PSO

To solve the problem of congestion management, each particle of the swarm chosen has a dimension of N-1 where N is the number of participants in the electricity market. Each dimension of a solution particle represents the amount of active power that a participant is willing to sell in the pool electricity market and the fitness of the particle is evaluated using the objective function (4), which is to minimize the cost of purchasing active power.The solution of the optimization problem is kept in the feasible space by a hybrid constraint handling technique. The technique combines the two method of constraint handling i.e.

i. A particle is reinitialized in the feasible space if the particle moves out of the feasible space in the position updation process. This strategy is used when the control variables i.e. P_{gi}move out of its bounds or when the power flows used in the iterative process does not converge.

ii. The position of *pbest* and *gbest* are allowed to update only when the particle is in feasible space. This strategy is applied when the MVA flow constraints are violated.

A. *PSO Algorithm for Congestion Management*

1. Choose the population size, inertia weight, acceleration coefficients and the maximum no iterations.
2. Initialize a feasible population of N-1 dimension, where N is the no participants in the electricity market.

3. Calculate the fitness of the individual particle and update the pbest of the particle and gbest of the swarm.
4. Update the velocity and position of each particle using equation (1) and (2).
5. Use the hybrid constraint handling technique to keep the solution in feasible space.
6. End the iterative process if no of iteration exceeds the maximum no of iteration or else go to step 3.

B. *C-PSO Algorithm for Congestion Management*

1. Choose the population size, inertia weight, acceleration coefficients and the maximum no iterations.
2. Initialize a feasible population of N-1 dimension, where N is the no participants in the electricity market.
3. Calculate the fitness of the individual particle and find the pbest of the particle and gbest of the swarm.
4. Initialize the iterative process and set the iteration count equal to 1.
5. From 2^{nd} iteration onwards calculate the fitness of the individual particle and update the pbest of the particle and gbest of the swarm.
6. If for the consecutive seven iteration there is no significant improvement in the gbest value sort the swarm from worst value to best value and reinitialize the first 10% particles with extremes of the search space.
7. Update the velocity and position and weight of each particle using equations (1),(2) and (3).
8. Use the hybrid constraint handling technique to keep the solution in feasible space.
9. End the iterative process if no of iteration exceeds the maximum no of iteration or else go to step 5.

V. Results and Discussion

The proposed C-PSO based algorithm described in previous section has been implemented using MATLAB programming on an IEEE 30 bus system and results are compared with PSO [6] and interior point based algorithm. In this paper, a pool model of electricity market is considered.

IEEE 30 bus system

The IEEE 30 bus is consists of 6 generator buses and 24 load buses.The test data for the system can be found in[7].The supply bid are taken as quadratic and the cost function is given as $C(P_{gi}) = a\,P_{gi}^2 + b\,P_{gi} + c$, where a, b and c are the constants whose values at the various generator buses are given in Table [1].

Table[1]:Coefficients of supply bids

GEN NO	BUS NO	*a*	*b*	*c*
1	1	0.038432	20	0
2	2	0.025000	20	0
3	5	0.010000	40	0
4	8	0.010000	40	0
5	11	0.010000	40	0
6	13	0.010000	40	0

The parameters used for conventional PSO and C-PSOare as follows:

Swarm size: 50;
Acceleration coefficients: (C1=C2=2);
Maximum number of iteration: 100;
Inertia weight (PSO): 0.5;
Inertia weight (C-PSO): maximum=0.9; minimum=0.4;

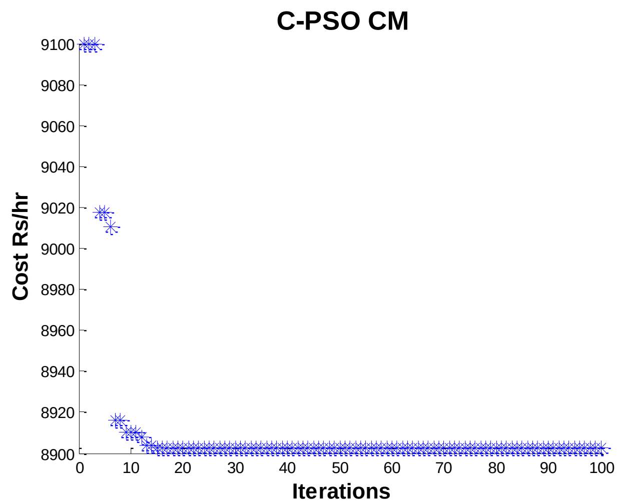

Figure 1. Optimal cost in each iteration using C-PSO

Figure 1.shows the convergence of the solution and the minimum cost at each iteration using C-PSO. Tables [2] shows the best, worst and mean value of the minimum cost of active power purchase given by using PSO and C-PSO based CM algorithms.The best, worst and mean values are calculated by twenty individual run of each algorithm.

TABLE[2]:RESULTS OF PSO AND C-PSO BASED CM ALGORITHM

	PSO	C-PSO
BEST(Rs/hr)	8906.09	8902.41
WORST(Rs/hr)	8908.90	8902.90
MEAN(Rs/hr)	8906.15	8902.42

As can be seen from Table [2] that the C-PSO based algorithm gives better result. The PSO algorithm as used in [4] is prone to be trapped in a local best position and introduction of the catfish particle in the swarm increases the capability to reach the global best position.

VI. Conclusion

In this paper the problem of congestion management in a pool market is solved by scheduling of active power of generators using C-PSO and PSO. The cost of purchase of active power is minimized; while taking operational constraints into consideration. The results obtained by implementing the C-PSO based algorithms on an IEEE 30 bus systemare compared with the PSO based algorithm and they show that C-PSO gives a moreeconomical solution for the congestion management problem as compared to PSO.

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