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Determination of Maximum Allowable Load of the Buyer Bus using New Hybrid Particle Swarm Optimization

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Abstract

This paper describes a novel method to estimate maximum allowable load at the buyer buses without violating transmission line flow limit for a wheeling transaction in a competitive electricity market. The problem is formulated as a non-linear optimization problem and the application consists of using a developed optimal power flow based on load maximization in each load bus by expanding the original PSO. A New Hybrid Particle Swarm Optimization (HPSO) is proposed to solve this problem by adding a Cauchy mutation on the best particle. In the context of electricity market, transmission pricing is an important tool to achieve an efficient operation of the electricity system. Optimal-wheeling price is also evaluated for the transaction under Maximum allowable load at buyer bus. The above technique is illustrated for the considered transaction on IEEE 30-bus system and Indian utility 69 bus systems

Keywords: Cauchy mutation, Hybrid Particle Swarm Optimization Independent Power Producer, Maximum allowable load, wheeling pricing, Wheeling Transaction.

Introduction

In the deregulation environment, generation, transmission and distribution are independent of each other. The restructured power sector introduces competition among producers and offer choices to the consumers. The regulated utilities and deregulated utilities are combined to form the concept of wheeling. Wheeling is the transmission of electrical energy from a seller to buyer through a transmission network owned by third party [1]. Wheeling of electricity takes place, when a customer purchases electricity from a source other than its own serving utility. The utility whose transmission network is used for wheeling transaction has to be paid for its service and for meeting the losses. Electricity wheeling has become one of the indispensable elements of power system deregulation. The problem of marginal costs based optimal wheeling rates considering losses, effects of line flow and voltage magnitude constraints has been discussed in [2,3].Caramanis et al., [4] has described wheeling rate evaluation simulator, which can be used to evaluate the marginal cost of wheeling between utilities, private users and private generators. The principle and the implementation of Mw-mile methodology to evaluate the usage of transmission network capacity for firm transmission services, including wheeling transaction discussed in [5]. Clayton et al., [6] described the incremental pricing concepts and incremental loss concepts for interchange costing and wheeling loss evaluation. The application of Optimal Power Flow (OPF) for the evaluation of wheeling and non-utility generation (NUG) related options have been discussed in [7].Kuwahata and Hiroshi [8] has explained utility-Co generator game for pricing power sales and wheeling fees. A methodology has been proposed to access the feasibility and pricing of wheeling transactions under deregulated environment of power industry. It is based on ATC and short run marginal cost as discussed in [9]. From the feasible transactions, least cost transaction is selected which will help the Independent Power Producer (IPP), to choose the best location for sale of power and also buyer to decide from which IPP they should buy power. Most of these models as reported in [10-16] mainly focus towards power flow and the ATC limits of power systems for total system loadability and generally, they are not addressing the problem of estimating maximum load at buyer bus during wheeling transactions without violating line flow limit.

An optimization-based scheme is proposed to solve this problem. However, the tool of analysis belongs to the evolutionary algorithm family. The application of PSO extensively used for some power system applications such as economic dispatch, OPF, and reactive Power planning as reported in [17-19]. In this paper, a new hybrid PSO (HPSO) is proposed. HPSO uses an idea from fast evolutionary programming (FEP) [20, 21] to mutate the best position by Cauchy mutation. It is to hope that the long jump from Cauchy mutation could get the best position out of the local optima where it has fallen. Comparison has been conducted between HPSO with Cauchy mutation (HPSOCM) and other Evolutionary technique PSO.

In the context of electricity market, transmission pricing is an important tool to achieve an efficient operation of the electricity system. Once the maximum allowable load and location has been identified, optimal wheeling price is evaluated for them by using the methods Mw mile method, Base method(BM), Module or Use method(MOU) and Zero Counter Flow(ZCF) method [22,23].

Two test systems i.e., IEEE 30-bus system and Indian 69-Bus utility bus systems with considered transactions used for validate the proposed technique. Simulation results has demonstrated that the proposed technique can be well used for locating buyer with maximum capacity and its transactions as well as a support tool for restructuring power system operation.

Hybrid Particle Swarm Optimization with Cauchy Mutation (HPSOCM)

The traditional PSO model was described by Dr. Kennedy and Dr. Eberhart in 1995. It consists of a number of particles moving around in the search space, each representing a possible solution to a numerical problem. Each particle has a position Vector $X_i = (x_{i1}, x_{i2}, ..., x_{in})$,a velocity Vector $V_i = (v_{i1}, v_{i2}, ..., v_{in})$ .In the PSO, the collective best position of all the particles taken together is termed as the global best position given as $Glbest_i = (\mathrm{glb}_{i1}, \mathrm{glb}_{i2}, ..., \mathrm{glb}_{in})$ and the best position achieved by the individual particle is termed as the local best or position best and for i^{th} particle given as $Pbest_i = (p_{i1}, p_{i2}, ..., p_{in})$. Particles uses both of these are information to update their positions and velocities are given in the following equations

$$V_i^{k+1} = \omega V_i^k + C_1 \times rand_1 \times (Pbest_i^k - X_i^k) + C_2 \times rand_2 \times (Glbest_i^k - X_i^k) \quad (1)$$

Where V_i^k is velocity of individual *i* at iteration *k*, ω is inertia weight parameters, C_1 and C_2 are two positive constants called acceleration constants, generally $C_1=C_2=2$, *k* represents iteration number, $rand_1$ *and* $rand_2$ are random values different for each particle and each dimension, X_i^k is position of individual *i* at iteration *k*, $Pbest_i^k$ is the best position of individual *i* at iteration *k*, and $Glbest_i^k$ is the best position of group *i* at iteration *k.*

The position of each particle is updated in the each iteration. This is done by adding the velocity vector to the position vector, i.e.

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

The accuracy and rate of convergence of the algorithm depends on the appropriate choice of particle size, maximum velocity of particle size and the inertia constant. If the velocity is higher than a certain limit, called V^{max}, this limit will be used as the new velocity for this particle in this dimension, thus keeping the particle within the search space. The particles have no neighborhood restrictions, meaning that each particle can affect all other particles.

Some theoretical results have shown that the particle in PSO will oscillate between their previous best particle and the global best particle found by all particles so far, before it converges. If the searching neighbors of the global best particle would be added in each generation, it would extend the search space of the best particle. It is helpful for the whole particles to move to the better positions. This can be accomplished by having a cauchy mutation on the global best particle in every generation. The one dimensional cauchy density function centered at the origin is defined by

$$f(x) = \frac{t}{\pi(t^2 + x^2)}, -\infty < x < \infty \tag{3}$$

Where $t > 0$ is a scale parameter.

The Cauchy distribution function is

$$F_t(x) = \frac{1}{2} + \frac{1}{\pi}\arctan\left(\frac{x}{t}\right) \tag{4}$$

The Cauchy mutation operator used in HPSO is described as follows:

$$W(i) = \frac{\left(\sum_{j=1}^{PopSize} V[j][i]\right)}{PopSize} \tag{5}$$

Where $V[j][i]$ is the i^{th} velocity vector of the j^{th} particle in the population, Pop Size is the Population Size. $W(i)$ is a weight vector with in $[-W_{\max}, W_{\max}]$, and $W_{\max}$ is set to 1 in this paper.

$$gbest'(i) = gbest(i) + W(i) * N(X_{\min}, X_{\max}) \tag{6}$$

Where N is a Cauchy distributed function with the scale parameter $t=1$, and $N(X_{\min}, X_{\max})$ is a random number with in $(X_{\min}, X_{\max})$, which is a defined domain of a test function.

The Pseudo code for HPSO algorithm with cauchy mutation is illustrated as below,

Begin
Initialize
While (not terminate-condition)
Evaluate
Calculate new velocity vectors
Update particle position
Update W[i]
if W[i]>W_{max},then W[i]=W_{max}
If end
Mutate gbest
Select gbest from the N particles after having N mutation
If the fitness value of gbest' is better than gbest
Then gbest=gbest'
If end
While end
End

Problem Formulation

Mathematically, each bilateral transaction between sellers at bus *k* and power purchaser at bus *j* satisfies the following power balance relationship. The conceptual modeling of wheeling transaction is that sellers and buyers encourage the trading between them without violating the transmission constraints,

$$P_{Gk}^{IPP} - P_{dj} = 0 \tag{7}$$

Where P_{dj} is buyer power at j^{th} bus.

A simultaneous wheeling transaction has been included in an '*n*' bus system. With the seller at the bus *k* and the buyer with a load at bus *j*, where *j* may be varied from *1* to *n* and *j* is not equal to *k*. Then, run the power flow program with all the generators of the utility held at fixed optimal setting of base case under these conditions. The first objective is to maximize the allowable active power load of each load bus and the second objective is to determine optimum cost of generation for the maximum allowable load condition during considered bilateral transactions

Objective 1

The maximization of load at buyer bus is done only on load buses (*j*), where *j* is varied from *1* to N_d.The maximum load location of buyer bus has been evaluated using HPSOCM.

The objective function for maximum allowable load at buyer bus is as follows,

Maximize active power load applied to the buyer bus *j*

$$\text{Maximize } P_{dj}^{allow} \tag{8}$$

Where 'P_{dj}^{allow}' denotes allowable load at bus *j*, which represents the increase in the system load from base load at buyer bus without violating the line flow constraints and voltage limit. The load at buyer bus '*j*' in steps from base case to maximum loading point until the system no longer has a solution, whose load model is given as below:

The basic load-flow equations are modified to include the power generation by IPP as follows: Let f_{Pi} and f_{Qi} be two reformulated functions defined as follows,

$$f_{Pi} = \sum_{j=1}^{NB} |V_i||Y_{ij}||V_j| \cos(\theta_{ij} + \delta_j - \delta_i) - (P_{Gi} + P_{Gk}^{IPP}) + (P_{di} + P_{dj}^{allow}), k \neq \text{slack} \tag{9}$$

$$f_{Qi} = \sum_{j=1}^{NB} |V_i||Y_{ij}||V_j| \sin(\theta_{ij} + \delta_j - \delta_i) - Q_{Gi} + Q_{Di}, j \neq \text{slack} \tag{10}$$

$$P_{Gi}^{min} \leq P_{Gi} \leq P_{Gi}^{max} \tag{11}$$

$$V_i^{min} \leq V_i \leq V_i^{max} \tag{12}$$

$$S_l \leq S_l^{max} \tag{13}$$

Where V_i and V_j are the voltage magnitude of bus *i* and *j*, δ_i and δ_j are the voltage angle of bus i and j, Y_{ij} and θ_{ij} are the magnitude and angle of Y_{ij} element in bus admittance matrix, P_{Gi} is the generated power at bus i, P_{Di} is the load power at bus i, P_{Gk}^{IPP} is the real power generation of IPP at bus k, N_d is number of load buses, NB is number of buses in the system, N_{pq} and N_{pv} are the set of PQ, PV buses, V_i^{min} and V_i^{max} are the minimum and maximum voltage limit at i^{th} bus, P_{Gi}^{min} and P_{Gi}^{max} minimum and maximum real power output of the generating unit at i^{th} bus, S_l^{max} is maximum apparent power flow on line l.

Objective 2

The objective function to determine optimum costof generation for considered transaction, it is stated as follows:

Minimize

$$\sum_{i=1}^{n} f_i(P_{Gi}) \tag{14}$$

Where

$$f_i(P_{Gi}) = a_i P_{Gi}^2 + b_i P_{Gi} + c_i \ \ \$/hr$$

Consider constant voltage magnitude is assumed throughout the network and the constraints are as follows,

$$\sum P_{Gi} + P_{Gk}^{IPP} = \sum P_{di} + P_{dj}^{allow} \tag{15}$$

$$P_{Gi}^{min} \le P_{Gi} \le P_{Gi}^{max} \tag{16}$$

$$P_{ij}(\delta) \le P_{ij}^{max} \tag{17}$$

Transmission Pricing Methodologies

The cost of the transmission network considers the impact of power flow due to bilateral exchange of power. Wheeling pricing is estimated using the following methods as discussed below:

Mw-mile method

Megawatt mile pricing generally involves using load flow analysis to find the power flows on the transmission network to determine transmission distance. These distances reflect the impact of a transmission agreement on the system.

$$P = \frac{CT}{\sum_i F_i \times L_i} \tag{18}$$

Where CT is the total Cost to share ($), F_i is Power flow in line *i* and L_i is line length (mile).The cost of transmission per megawatt-mile is the total cost averaged over Megawatt-miles of usage. The change in power flows at every transaction is calculated. The difference in Power is obtained by subtracting the power flow due to transaction with power flow due to base case.

Base method(BM)

In this method, the pricing is calculated for power flow in each line due to transaction. Here, the negative value of power flow is also taken for finding transmission pricing.

$$R(t) = \sum_i C_i \frac{F_i(t)}{\sum_s F_i(s)} \tag{19}$$

Where C_i is total cost in line *i*, $F_i(t)$ is power flow due to transaction *t* and $F_i(s)$ is sum of power flow transactions

Module or Use method(MOU)

Module or Use method considers only the magnitude of load flow, not the direction of flow due to transaction. The transmission pricing due to transaction *t* can be calculated as;

$$R(t) = \sum_i C_i \frac{|F_i(t)|}{\sum_s |F_i(s)|} \tag{20}$$

Where Ci is total cost in line *i*, $|Fi(t)|$ is the power flow due to transaction *t* and $|Fi(s)|$ is the sum of power flow transactions

zero counter flow method(ZCF)

This method takes only positive power flow for finding pricing. The negative power flows are assumed zero. The change in power flow is obtained by adding all transaction only with positive flows. (21)

and

$$FD(t) = \begin{cases} F_k(t) & \text{if } F_k(t) > 0 \\ 0 & \text{if } F_k(t) \le 0 \end{cases} \tag{22}$$

$$R(t) = \begin{cases} \sum_i C_i \frac{F_i(t)}{\sum_s FD_i(s)} & \text{for } F_i(t) \le 0 \\ 0 & \text{for } F_i(t) > 0 \end{cases}$$

Where C_i is total cost to share in line *i*, $F_i(t)$ is power flow in line due to transaction *t*, The term $FD_i(s)$ shows the Impacts for provoking the transaction *t* in line *i*. This will increase the active power flow in the lines.

Algorithm for estimating maximum allowable load at buyer bus

The objective function is to maximize allowable load at buyer bus using HPSOCM.

Load during each transaction is assumed as the particle to be optimized.

Step 1: Calculate base case values.

Step 2: Set IPP at bus k.

Step 3: Set load point count j=1.

Step 4: Specify the maximum and minimum limits of generation power of each generation units and IPP, maximum number of iterations to be performed.

Step 5: Particles are generated and initialized with position values and velocity.

Step 6: The binding constraints fitness values for the particles are determined. If a particle does not satisfy the fitness requirement, it is regenerated.

Step 7: Execute the PSO operator on the particles.

Step 8: The optimal objective fitness values are calculated for all the particles.Then the values of position best and global best are determined.

Step 9: Position and velocities of particles are updated.

Step 10: Perform mutation process to replace the worst particles.

Step 11: If the maximum number of iteration is exceeded or some pre specified an exit criterion is satisfied, then goes to step 12. Else, update the time counter.

Step 12: Output the particle with the maximum fitness values in the last generation. Calculate the optimum value with the objective function (Eq (8)) subjected to the constraints (Eq(9)-Eq(13)), using HPSOCM.

Step 13: Increment j by 1 and if j is less than or equal to number of load buses go to step 5. Otherwise, go to next step.

Step 14: If all the transactions are simulated, determine the buyer bus for maximum allowable load and its location.

Step 15: Find the optimal pricing as per section 4 and optimal generation cost (Eq (14)-Eq (17)) for the considered transaction.

Results and Discussion

For the present study, reactive power demand at load buses has been taken constant. The study has been conducted on IEEE 30-bus and Indian utility 69-bus utility systems, slightly modified to represent simultaneous of wheeling transaction in a deregulated market.

For both test systems, the results are obtained by the following approaches:

- Estimating maximum Load of buyer bus by HPSOCM algorithm
- Optimizing transmission pricing for considered transaction
- Optimal generation cost for considered transaction

The influence of the PSO parameters, the inertia weight, and population size, constants C_1 & C_2, on the convergence of the algorithm has been studied. The size of particles has been increased from 10 to 100 in steps of 10 and the number of best particle for this problem is found to be 60, the inertia constant varied from 0.4 to 0.9 and optimal value for this problem is found to be 0.5, Maximum number of iteration has been taken as 100. The minimum solution was obtained for 100 trial runs. Simulation studies have been conducted on Intel(R) core i5, CPU M430 @ 2.27 GHz processor under Mat Lab 7 environment. The adopted parameters in the algorithms are given in Table1.

Table 1: Parameter values for PSO and HPSOCM for the two test systems.

Parameters	IEEE 30 bus		INDIAN 69 Bus	
	PSO	HPSOCM	PSO	HPSOCM
Population	60	60	60	60
C_1	2	2	2	2
C_2	2	2	2	2
Inertia weight (W)	0.5	0.5	0.5	0.5
W_{max}	-	1	-	1
N	-	25	-	25
X_{min}	-	0	-	0
X_{max}	-	1	-	1
Iterations	100	100	100	100

IEEE 30-bus system

The numerical data for IEEE 30-bus system is taken from Ref. [24]. This system has 6 generators, 30 buses,41 transmission lines. The generators are connected at the buses 1,2,13,22,23 and 27. For this system, bus 1 is slack bus and there are 24 load buses. The algorithm conducts the OPF by satisfying all the power flow constraints and estimates the maximum load at buyer buses without violating transmission constraints. In each bilateral transaction, the load at buyer bus is increased until the system no longer has a solution by using HPSOCM and its effectiveness is compared with PSO To calculate the maximum allowable real power load at buyer bus without violating of the line flow limit, the following methodology is used. Once the location and value of IPP is identified, the PSO and HPSOCM techniques optimize the amount of real power load at buyer buses during wheeling transaction. However, a feasible transaction has been executed by optimum value of IPP with maximum allowable load without violating line flow limit. Two cases has been outlined below for detailed results discussion. Case 1 deals with the problem of maximum allowable load of buyer buses as per objective, which is given in section3. Case 2 explains the effectiveness of wheeling transaction if it crosses the maximum allowable load of buyer bus. For both cases, a transmission-pricing methodology has been introduced for considered transaction and finds the optimum wheeling cost.

Case 1: Let us connect that independent Power producer of IPP of 144.5 MW is connected at bus 10. All other generators of the system are held at optimal position. Therefore, 7 generator buses and 23 load buses in the system Note that only MW overloading of transmission lines are considered. IPP is interested to have a wheeling transaction of all load buses of 30-bus system. The algorithm conducts the OPF by satisfying all the power flow constraints and finds the maximum MW load of buyer buses. Figure.1 presents the maximum allowable load that can be supplied by IPP through various wheeling transactions at different load points without violating transmission line flow limit. The maximum allowable load 98.75 MW has been found at bus 5 at 17th iteration by using HPSOCM. However, it is only 97.88MW with PSO and the results are obtained only in the 24th iteration.

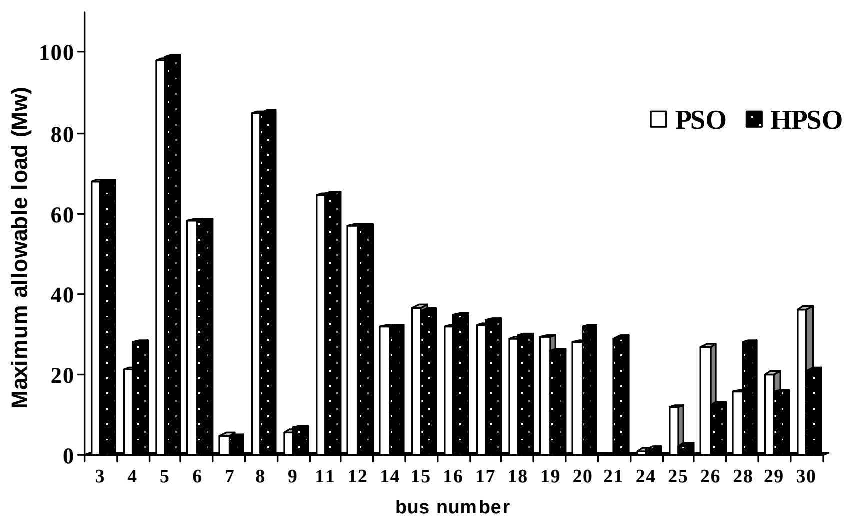

Figure 1: Estimation of Maximum allowable load supplied by IPP through wheeling transaction for IEEE 30-bus system.

Case 2: The load at buyer bus is slightly increased to 98.85 MW at bus 5. Figure 2 shows summary of the transmission lines overloading for the transaction. Line 13 (i.e., between buses 10 and 6) is congested and it exceeds about 107.7% of their respective MVA limit. This overload can be alleviated by load curtailment or by generator rescheduling.

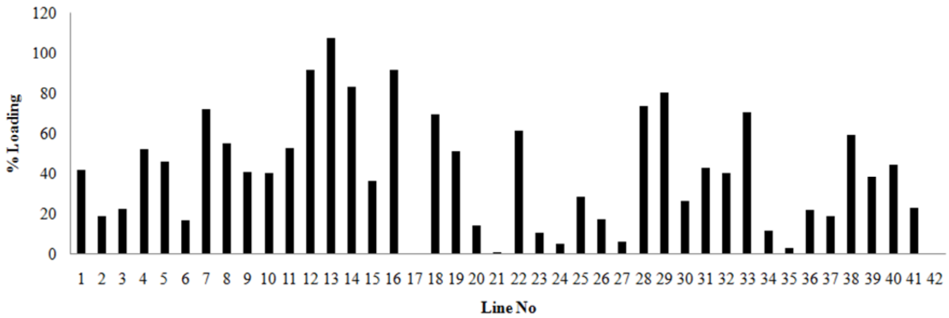

Figure 2: Percentage of over loading for the Transaction 10-5 for case 2.

The wheeling charges for the transactions are calculated by different methods as discussed in section 4 and it has been presented in Table 2. The change in the magnitude of power flow on the system caused by the wheeling transaction is taken into consideration in order to assist in the allocation of the wheeling cost to each of the wheeling transaction.

Table 2: Comparison Of Pricing Methods for case 1-IEEE 30 Bus System.

Transactions	Mw-mile	Base Method	Module Or Use	Zero Counter Flow
10-3	95.277	101.833	80.323	88.630
10-4	83.983	156.614	94.272	86.088
10-5	68.910	407.743	68.681	74.270
10-6	86.863	670.999	90.460	62.144
10-7	73.996	-161.709	105.107	100.859
10-8	99.269	463.206	101.860	71.862
10-9	86.465	-267.491	111.686	105.767
10-11	101.825	430.820	99.564	73.365
10-12	94.758	-83.573	106.342	97.233
10-14	100.807	67.533	111.701	90.222
10-15	93.095	63.278	91.046	90.419
10-16	93.704	33.683	79.561	91.792
10-17	104.133	683.876	114.556	59.897
10-18	99.353	219.611	85.836	83.165
10-19	93.087	114.623	79.347	88.037
10-20	84.535	104.016	75.282	88.529
10-21	85.856	117.645	78.017	87.897
10-24	85.786	-320.713	83.302	108.237
10-25	86.454	-297.102	81.885	107.142
10-26	82.719	-222.08	78.207	103.660
10-28	77.490	-357.461	81.482	109.942
10-29	85.097	-34.953	74.547	94.977
10-30	86.528	159.595	76.927	85.854
Total cost ($/hr)	2050	2050	2050	2050

The total transmission system cost is then the sum of all the power flow-mile and this provides a measure of how much each transaction uses the transmission system, the price is proportional to the transmission usage by respective transactions. The power flow miles of each transmission line are totalled up to represent the amount of the transmission resources used by the corresponding transaction. All the line lengths are assumed to be 100 miles and the Transmission cost is taken to be 50$/MW-Mile-annum.

Figure 3 shows the percentage of cost contribution to the considered transaction 10-5 under maximum allowable load at buyer bus 5 for case 1and case 2. It is evident that module or use (MOU) method has shown the minimum contribution of cost for the transmission service in both cases.

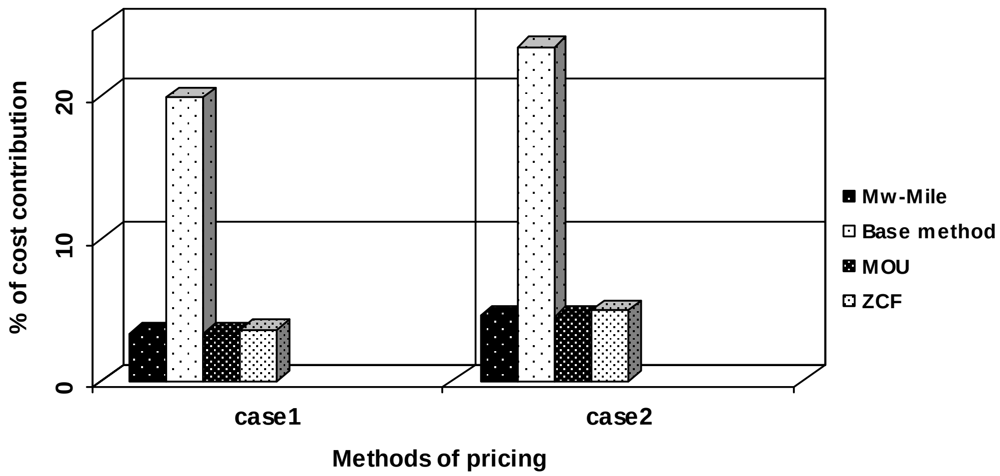

Figure 3: Wheeling cost allocation to transactions for IEEE 30 bus system.

Indian-69 Bus Utility System

Indian utility 69-bus system has 13 generators and 99 transmission lines. The bus data for this system has been taken from TamilNadu Electricity Board report (2003-2004) [25]. Tamil nadu is one of the southern states of India and this system is under the control of Tamil Nadu electricity Board, a state government owned Power Corporation. The One line diagram of Indian utility-69 bus system is shown in figure 4.

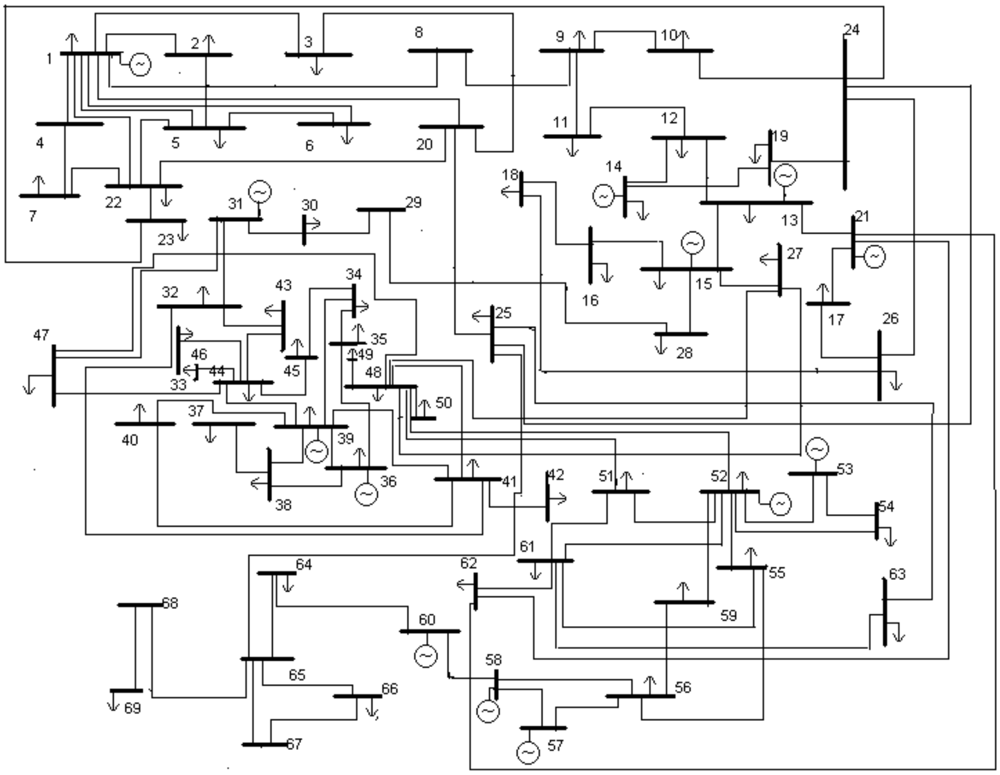

Figure 4: One line diagram of Indian utility-69 bus system.

Case 1: Let us connect IPP of 260.3 MW at bus no 7. Figure 5 presents the maximum allowable load that can be supplied by IPP through various wheeling transactions at different load points without violating transmission line flow limit. In addition, the maximum allowable load has been identified at bus no 2 and its value is 201.45 MW using HPSOCM.

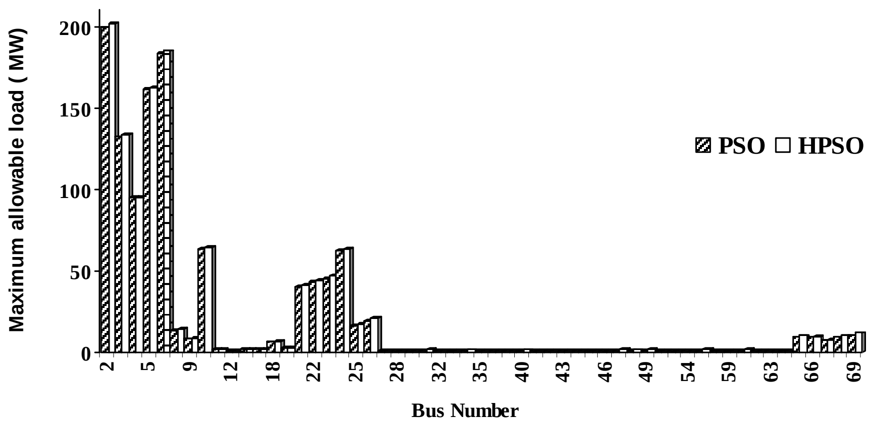

Figure 5: Estimation of Maximum allowable load supplied by IPP through wheeling transaction for Indian-69 bus utility system.

Case 2: The load at buyer bus is slightly increased to 201.55 MW at bus 2. Line 17 (i.e., between buses 10 and 9) and line 18 (i.e., between buses 11 and 9) are congested and it exceeds about 108 % and 117.5% of their respective MVA limit.

Let us assume all the line lengths100 miles. Transmission cost is 50 $/MW-Mile-annum. Figure 6 presents a graph that shows the percentage of cost contribution to the transaction 7-2 under maximum allowable load at bus 2. The total transaction cost is obtained about 4800 $/hr. It is important to mention that Module or Use (MOU) method has shown the minimum contribution of cost for transmission service.

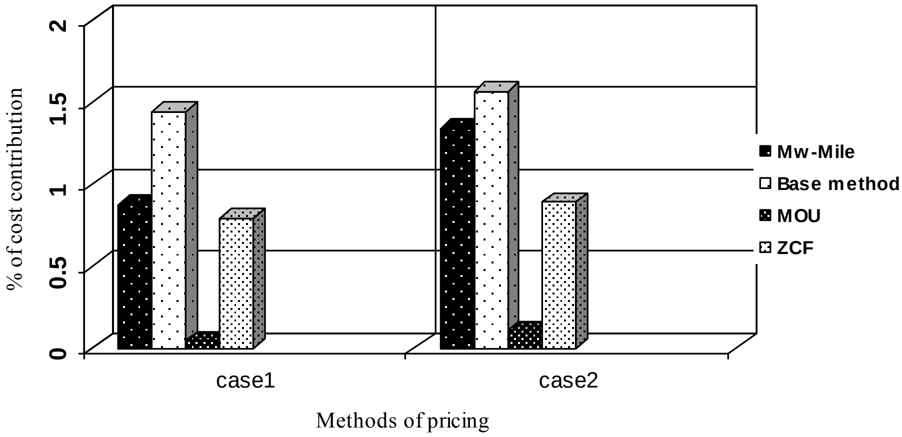

Figure 6: wheeling cost allocation to transactions for Indian utility-69 bus system.

Optimal generation cost for the considered transaction

The HPSOCM like the original PSO algorithm was originally proposed for continuous problems. HPSOCM has been tested for convergence on simple generation cost optimization problems. Generator bus data for Indian 69 bus utility system and cost coefficient for IPP are given in Appendix 1 and 2. Figure 7, Figure 8 and Table 3 shows the evolution process of the function values for HPSOCM and PSO employed for IEEE 30 bus and Indian 69 bus utility system.

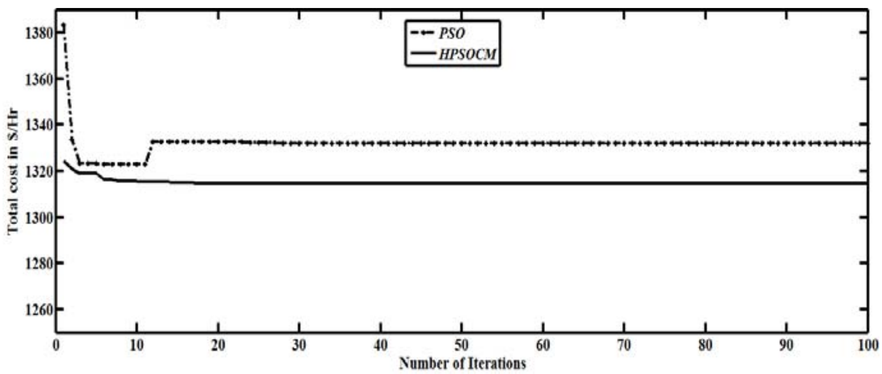

Figure 7: Comparison between PSO and HPSO for IEEE 30 bus system.

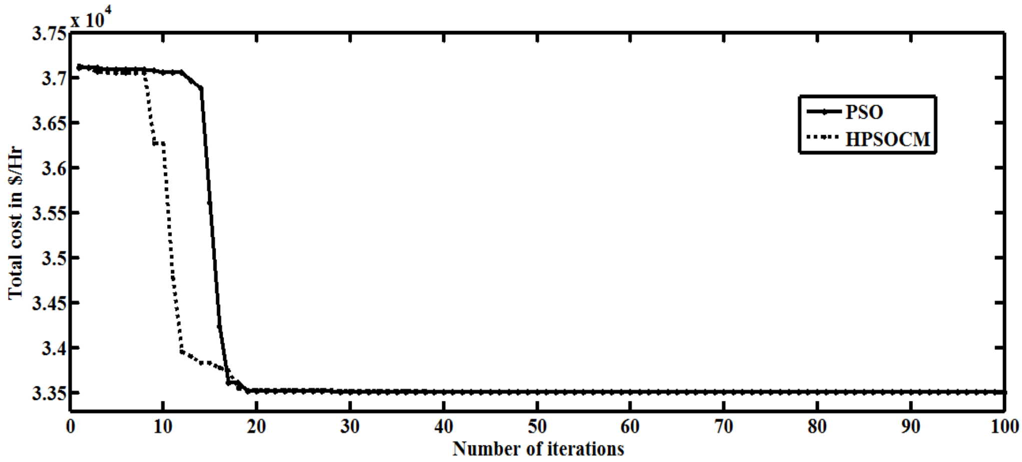

Figure 8: Comparison between PSO and HPSO for Indian utility 69-bus system.

Table 3: Optimum cost of generation for test systems using HPSOCM and PSO.

Test system	**IEEE 30 bus system**		**Indian utility69 bus**	
Algorithm	PSO	HPSOCM	PSO	HPSOCM
Total cost of generation in $/hr	1326.8754	1314.6892	33517.2418	33517.2391
Convergence Iteration	12	8	20	17
Computation time in sec	0.6826	0.6156	0.7658	0.7408

For the simple fuel cost functions, HPSOCM and PSO performed equally well at the beginning because the particles at that time are not good enough so that both methods could improve well. Once the particles in the populations are close to the best particle, the convergence of PSO becomes slower because the search steps in PSO become smaller. With the help of cauchy mutation on the best particles, HPSOCM could move the best particle away from the rest of particles in the population so that the fast speed could remain through the whole evolution process. Because of such mutations made on the best particle, HPSOCM could successfully find better solutions while maintaining fast search speed. On the other hand, PSO could be easily tracked into local minima without the mutation done on the best particle.

Conclusion

The proposed algorithm hybrid particle swarm optimization incorporating cauchy mutation operator into Particle Swarm Optimization has been successfully applied to estimate the maximum allowable load of buyer bus. From the result obtained, it is proved that HPSOCM is having faster convergence and better global search ability on those maximum allowable loads and total fuel cost of buyer buses compared to the standard PSO. It also suggests that a cauchy mutation on the best particle alone might not be enough to prevent the search from falling in the local optima. It is evident from the simulation studies that this approach is simple, easy to implement, converges at a faster rate, and can be used to other optimization problems as fine. Also, transmission-pricing methodologies are introduced and optimum price is determined for the transactions under maximum allowable load at buyer bus. The validity of the proposed method has been illustrated with IEEE 30 and Indian utility 69 bus test systems. The proposed method is completely free from complex mathematical formulation and provides quite encouraging results which will be useful for deregulated environment

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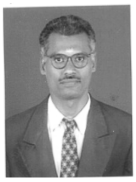

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Appendix. 1: Generator bus data for Indian 69 bus utility system.

Bus No.	P_{min} (MW)	P_{max} (MW)	Q_{min} (MVAR)	Q_{max} (MVAR)	a_i \$/MW^2-h	b_i \$/MW-h	c_i \$/h
1	0	900	-300	200	0.0085	6.0	55
13	0	1100	-300	200	0.0085	6.0	55
14	0	350	-150	100	0.0080	5.5	90
15	0	500	-200	100	0.0055	4.0	45
21	0	250	-100	80	0.0045	1.6	25
31	0	200	-90	80	0.0045	1.6	25
36	0	150	-90	80	0.0045	1.6	25
39	0	450	-200	100	0.0055	4.0	45

52	0	850	-300	200	0.0085	6.0	55
53	0	60	-25	25	0.0025	0.85	15
57	0	200	-90	80	0.0045	1.6	25
58	0	200	-90	80	0.0045	1.6	25
60	0	100	-100	70	0.0045	1.6	65

Appendix 2: IPPs-Generator Data.

Test Systems	P_{max} (MW)	a_i \$/MW^2-h	b_i \$/MW-h	c_i \$/h
IEEE 30-bus system	144.5	0.02	2	0
INDIAN 69-bus utility system	260.3	0. 0.0035	3	0