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NOVEL PSO STRATEGY FOR TRANSMISSION CONGESTION MANAGEMENT

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ABSTRACT

In post deregulated era of power system load characteristics become more erratic. Unplanned transactions of electrical power through transmission lines of particular path may occur due to low cost offered by generating companies. As a consequence those lines driven close to their operating limits and becomes congested as the lines are originally designed for traditional vertically integrated structure of power system. This congestion in transmission lines is unpredictable with deterministic load flow strategy. Rescheduling active and reactive power output of generators is the promising way to manage congestion. In this paper Particle Swarm Optimization (PSO) with varying inertia weight strategy, with two variants e1-PSO and e-2 PSO is applied for optimal solution of active and reactive power rescheduling for managing congestion. The generators sensitivity technique is opted for identifying participating generators for managing congestion. Proposed algorithm is tested on IEEE 30 bus system. Comparison is made between results obtained from proposed techniques to that of results reported in previous literature.

KEYWORDS

Electricity Market, Generator sensitivities, Particle Swarm Optimization, Rescheduling, Transmission Congestion.

1. INTRODUCTION

The problem of transmission congestion is predominating in deregulated electricity market structure as the existing lines are originally designed for vertically integrated unbundled operation. A transmission line is said to be congested when it operates closure to its operating limits. Under competitive environment large units of Generating Companies may offer lower electricity price to customers for profit maximization, this may change the power flow pattern and the transmission lines are often driven close to their thermal limits in order to satisfy the increased electric power consumption and trades due to increase of the unplanned power exchanges. If the exchanges were not controlled, some lines located on particular paths may become congested. To relieve the line from congestion and to ensure the secure operation of power system in a complex electricity market, appropriate congestion management strategy necessitates to be implemented. Congestion can be reduced by generation re-dispatch, load re-dispatch, reactive power support, and transmission system expansion. In [1] PSO is used to solve multi-objective problem formulation for CM, where generator rescheduling is formulated as an optimization problem with the objective of obtaining minimum rescheduling cost and proposed objective of achieving minimum real power loss. A vector evaluated particle swarm optimization is applied to solve CM optimization problem in electricity market [2]. PSO is implemented to determine optimal sizing of static var Compensators (SVCs) for minimization of transmission losses considering cost function [3]. In objective function installation of SVC cam be calculated using the cost function. The result obtained with PSO is compared with Bee Algorithm (BA).

In [4] a comprehensive coverage of different PSO applications in solving optimization problems in the area of electric power systems is presented. It highlights the PSO key features and advantages over other various optimization algorithms. Furthermore, recent trends with regard to

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PSO development in this area are explored.PSO algorithm for the solution of nonlinear optimization problem of CM is implemented in [5]. The problem formulation involves objective function which minimizes the total cost incurred for adjusting real power generation of the participating generators and the various constraints represents final powers as a function of market clearing values. upper and lower limits for real and reactive power of generators, upper and lower bound for real power adjustment of the participating generators, incremental and detrimental change in real power of generator line loading limit, lower and upper bound for load bus voltages. In this paper a novel PSO is implemented for optimal rescheduling of active and reactive power output of generators. In addition to its classical version PSO with varying inertia weight strategy is implemented on IEEE 30 bus test system.

2. PROBLEM FORMULATION

To manage congestion within the constrictions, problem formulation must be carefully done by considering all probable factors that affects the system. In the proposed strategy of congestion management, rescheduling of generator outputs is considered. The problem of optimum rescheduling of generator outputs is formulated including objective function and constraints.

2.1. Objective function

Objective of the work is to relieve the line from congestion and minimize the rescheduling cost of generators participating in managing congestion. The active and reactive power rescheduling costs of generators for congestion management based on the bids received is given by-

$$\text{Minimize} \sum_{g}^{Ng} C_{Pg}\left(\Delta P_g\right)\Delta P_g + \sum_{g}^{Ng} C_{Qg}\left(\Delta Q_g\right)\Delta Q_g \tag{1}$$

Where:

C_{Pg}: Cost of the active power rescheduling corresponding to the incremental/ decremental price bids submitted by generator-g participating in congestion management.
ΔP_g : Active power adjustment of the generator-g.
ΔQ_g : Reactive power adjustment of the generator-g.
$C_{Qg}(\Delta Q_g)$: Cost of the reactive power rescheduling of generator-g participating in congestion management. It is expressed as:

$$C_{Qg}\left(\Delta Q_g\right) = \left\{C_g^P(S_{Gmax}) - C_g^g\left(\sqrt{S_{Gmax}^2 - \Delta Q_g^2}\right)\right\} \times \varphi \tag{2}$$

Where, C_g^P is the cost of active power generation of generator *g* and is expressed as a quadratic function as

$$C_g^P\left(\Delta PG_{gn}\right) = a_n\left(\Delta PG_{gn}^2\right) + b_n\left(\Delta PG_{gn}\right) + c_n \tag{3}$$

2.2. Constraints

To ensure the operation of system within operating range with feasible solutions inequality and equality constraints are incorporated. In the present work constraints are power flow constraint (4), operating limit constraints (5) (6)

Subject to

$$\left(\sum_{g}^{Ng}\left((GS_{pg})\Delta P_g\right) + P_{ij}^{o}\right)^2 + \left(\sum_{g}^{Ng}\left((GS_{qg})\Delta P_g\right) + Q_{ij}^{o}\right)^2 \leq \left(S_{ij}^{max}\right)^2 \tag{4}$$

$$P_g - P_g^{min} = \Delta P_g^{min} \leq \Delta P_g \leq \Delta P_g^{max} = P_g^{max} - P_g \tag{5}$$

$$Q_g - Q_g^{min} = \Delta Q_g^{min} \leq \Delta Q_g \leq \Delta Q_g^{max} = Q_g^{max} - Q_g \tag{6}$$

Where:

GS_{pg}: Active power generator sensitivity
GS_{qg}: Reactive power generator sensitivity

3. PARTICLE SWARM OPTIMIZATION

Particle swarm optimization is a meta- heuristic optimization technique first introduced by Kennedy and Eberhart in 1995[6].The original version of PSO can only deals with nonlinear continuous optimization problems. With further advancement in the algorithm PSO can be implemented to complex problems of engineering and sciences to calculate global optimal solution. It is an efficient addition to the class of population based search techniques. PSO algorithm is on the whole inspired by social behaviour of organisms like shoaling of fish, the swarming of insects. In its colonial form, PSO initializes with random particle generation and velocity vector is used to update the particles. The best position visited during its flying tour in the problem search space referred to as personal best position (p-best) , The best position visited by all the particle is memorized, i.e., the best position among all p-best positions referred as global best position (gbest), Objective function is evaluated every solution produced in an iteration. This process continues until final criterion is achieved which either can be assigned as desired solution or number of iterations.

Let an n dimensional search space with N no. of particles, at an instant t particle i have its position defined by X_t^i and velocity byV_t^i. Velocity and position of each particle in the next generation can be calculated as-

$$V_{t+1}^i = w \times V_t^i + c1 \times rand() \times \left(P_t^i - X_t^i\right) + c2 \times rand() \times (P_t^g - X_t^i) \tag{7}$$

$$X_{t+1}^i = X_t^i + V_{t+1,}^i \forall i = 1,2 \ldots\ldots N \tag{8}$$

Where N is number of particles in the swarm, w is Inertia weight, c1&c2 are acceleration constants, rand () is uniform random value between 0 to 1, P_t^g is global best at generation t,P_t^i is best position that particle i could find so far. The first part of equation (8) represents the inertia of previous velocity, second part is cognition part and tells about the personal information of particle and third part is social component as it represents information among particles.

4. PSO WITH NATURAL EXPONENT INERTIA WEIGHT STRATEGY

Inertia weight in PSO plays vital role in exploring the solutions. It determines the contribution of rate of velocity obtained in previous step to the present. In basic PSO of Eberhart and Kennedy there was no inertia weight. First time Shi and Eberhart [7] introduced the concept of constant inertia weight. Further the concepts of varying inertia weight strategies were presented in [8]. In this paper improved PSO with two natural exponent strategies e1-PSO and e-2 PSO is used to get better results as compared to standard PSO. The variation of inertia weight with each iteration, for e1-PSO and e-2 PSO is as follows.

$$w(t) = w_{min} + (w_{max} - w_{min}) \cdot e^{\frac{iter}{\left(iter_{max}/_{10}\right)}} \tag{9}$$

$$w(t) = w_{min} + (w_{max} - w_{min}) \cdot e^{-\left[\frac{iter}{\left(iter_{max}/_{4}\right)}\right]^2} \tag{10}$$

5. CASE STUDY

Simulation studies were carried out on Intel Core 2 Duo processor, 2GB of RAM, 2.20 GHZ system in MATLAB 7.6 platform. The algorithm has been tested on IEEE 30 bus system [9]. IEEE 30 bus system consists of 6 generators, 24 load buses and 41 branches. Generator at slack bus is numbered as 1, while remaining are taken as 2,3,4,5 and 6. Numbering of load buses is taken from 7 to 30. Generating unit characteristics are given in table 1. Details of congested line and generator sensitivity values corresponding to the congested line are given in table 2 and 3.Line between bus 1 and 7 are congested, the rated MVA is 130 and actual flow is 138MVA. Generator data is given in table 1. Generator active and raective power sensitivities are given in table 2.

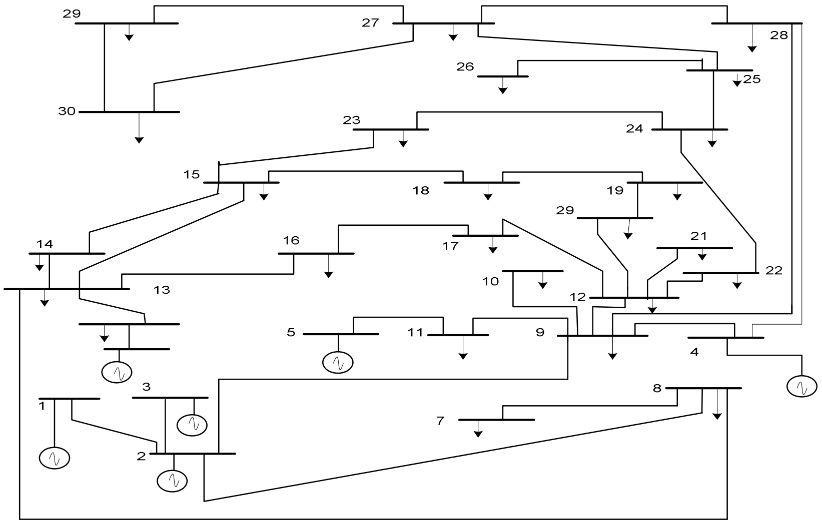

Figure1. Modified IEEE 30 bus system

Table 1: Generating unit characteristic of IEEE 30 bus system.

Unit	Cost Coefficients			Generator Limits	
	a ($\$/MW^2h$)	b ($/MWh)	c ($/h)	Pgmin (MW)	Pgmax (MW)
1	0.00375	2	0	50	250
2	0.0175	1.75	0	20	80
3	0.0625	1	0	15	50
4	0.00834	3.25	0	10	35
5	0.025	3	0	10	30
6	0.025	3	0	12	40

Table 2. Generator sensitivities

Unit	1	2	3	4	5	6
GS Pg	0.00	-0.85	-0.78	-0.68	-0.66	-0.64
GS Qg	-0.77	-0.86	-0.74	-0.78	-0.76	-0.77

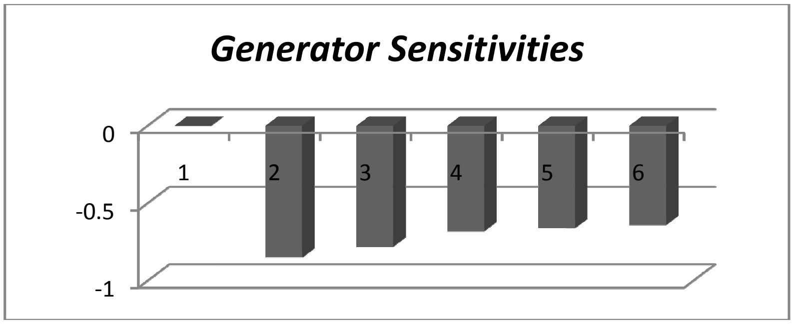

Figure 2. Plot of active power generator sensitivities of IEEE 30 bus system

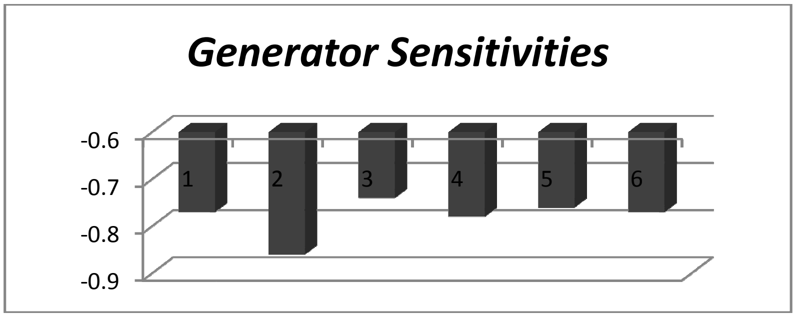

Figure 3. Plot of reactive power generator sensitivities of IEEE 30 bus system

6. PSO ALGORITHM FOR VARYING INERTIA WEIGHT STRATEGY

Step 1: Select PSO parameters – acceleration coefficients c1 & c2, inertia weight w, population size
Step 2: Initialize particles with their position and velocity
Step 3: Initialize $p_{best\ i}$ and g_{best}
Step 4: Set iteration count =0
Step 5: Calculate position matrix X_t^i
Step 6: Evaluate objective function
Step 7: Is objective value is greater than $p_{best\ i}$?
If yes, set it as new $p_{best\ i}$ & go to next step.
Else go to next step
Step 8: Is fitness value is greater than g_{best}?
If yes, set it as new g_{best} & go to next step.
Else go to next step
Step 9: Update Position of Particles by Using Equation (8)

Step10: Check whether stopping criteria (maximum number of iterations) reached?
If yes then got to step 14
Else go to next step.
Step11: Calculate inertia weights by using equation (9) & eq. (10).
Step12: Update velocity of particles using eq. (7).
Step13: Update position of particles using eq. (8).
Step14: Check for stopping criteria
If iterations < max. no. of iteration then increase iteration count by 1 & go to step 5.
Else go to step 14.
Step15: Final g_{best} position of particles is optimal solution.

7. RESULT AND COMPARISONS

Table 4: Comparisons of results on IEEE 30 bus system

		Result Reported in [10]	PSO	e1 -PSO	e2 -PSO
Active Power Rescheduling (MW)	ΔPg1	-50.09	42.4795	54.8940	3.6139
	ΔPg2	Not participated	37.6121	1.8665	36.7628
	ΔPg3	17.00	-4.0184	12.9445	15.3151
	ΔPg4	24.43	7.5377	2.7328	10.2114
	ΔPg5	Not participated	-10.9927	-15.2149	-5.9628
	ΔPg6	6.08	-3.6867	6.2443	-3.6899
Total Active Power Rescheduling (MW)		96.60	68.9315	63.4672	56.2505
Total active power rescheduling Cost ($/h)		28901	23117	19450	18609
Reactive Power Rescheduling (MVAR)	ΔQg1	-35	34.9709	6.1094	28.6309
	ΔQg2	Not participated	50.3687	5.4376	32.9824
	ΔQg3	58.20	27.652	37.6894	-9.6063
	ΔQg4	27.29	0.98	35.2871	17.4261
	ΔQg5	Not participated	13.8934	-0.9634	8.1270
	ΔQg6	-39.31	3.2213	11.6435	11.8535
Total Reactive Power Rescheduling (MVAR)		159.80	131.0863	95.2036	89.4136

Total reactive power rescheduling Cost ($/h)	7048	5342	4352	4075
Time (Sec)	Not Reported	0.40640	0.39785	0.39812

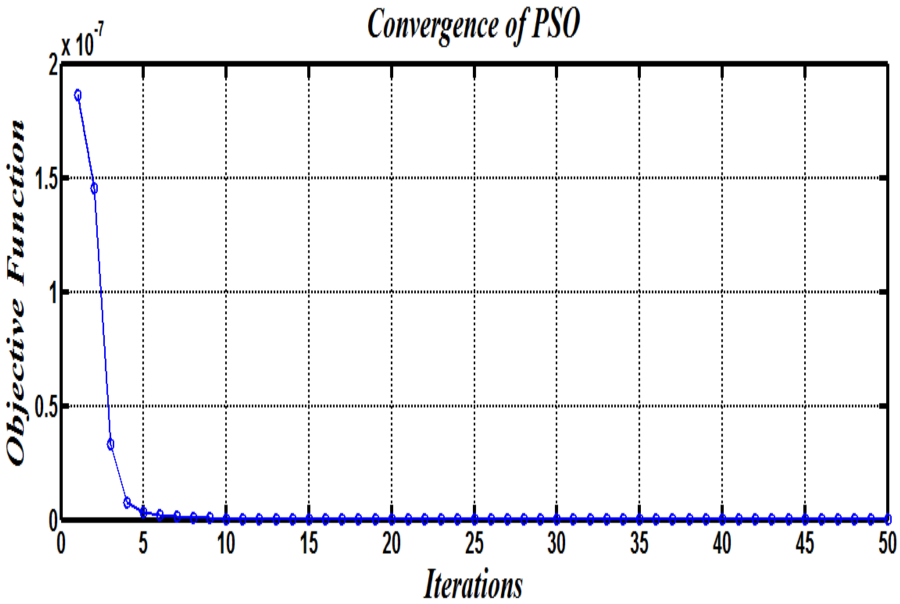

Figure 4.Convergence characteristic of PSO (IEEE 30 Bus system)

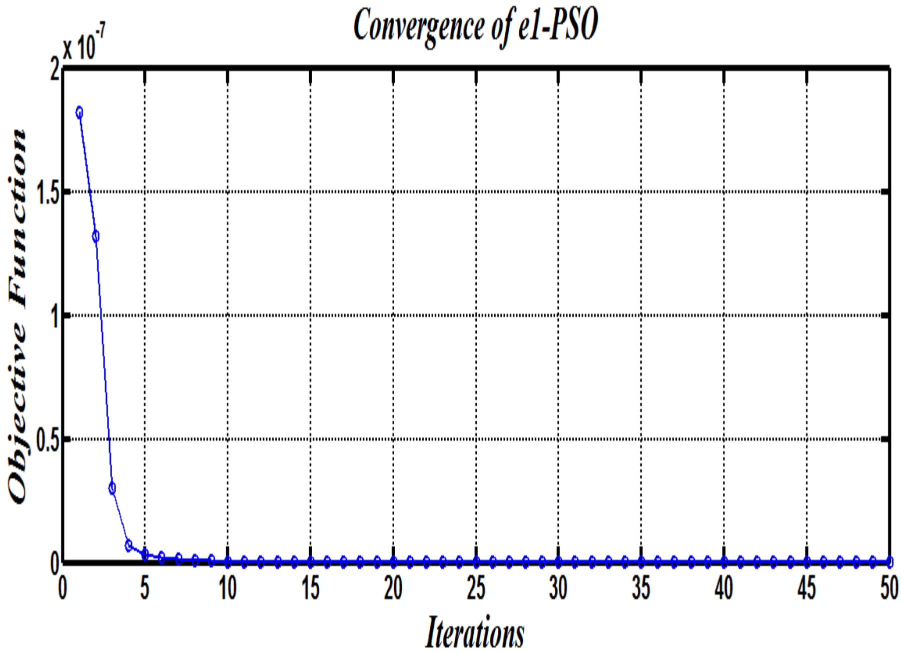

Figure 5.Convergence characteristic of e1-PSO (IEEE 30 Bus system

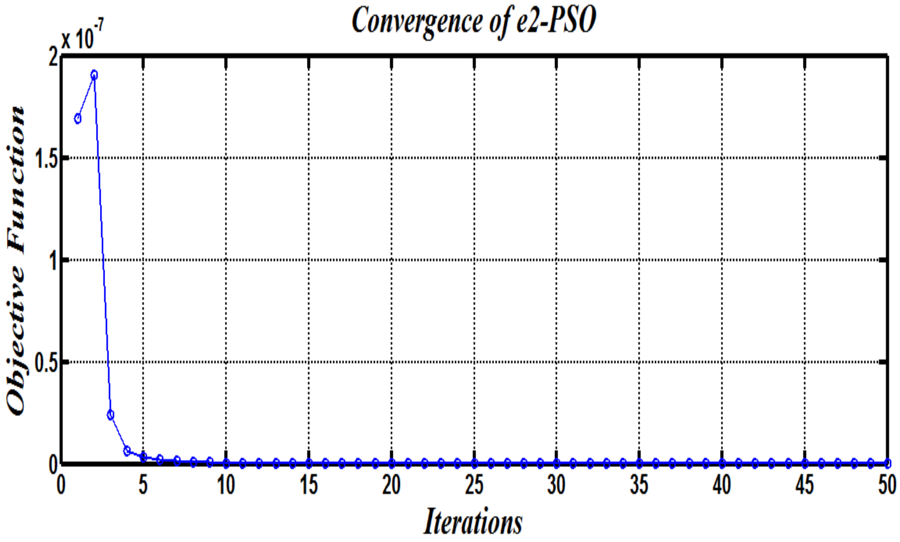

Figure 6.Convergence characteristic of e1-PSO (IEEE 30 Bus system)

8. CONCLUSION & FUTURE SCOPE

In this paper optimal active and reactive power rescheduling output of generators are calculated for transmission congestion management to ensure the reliability of the deregulated power system under consideration. The results obtained by original PSO, e1-PSO and e2-PSO are compared for better convergence. Results show that modified PSO with varying inertia weight in successive iterations exhibits better results. Techniques are implemented on IEEE 30 bus system. All generators are selected for congestion management due to few numbers. The proposed technique can be further improved by considering technical factors like transmission losses. Better convergence of results can be obtained by hybrid PSO techniques.

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