

Artificial Bee Colony Algorithm Based Congestion Management in Restructured Power System

R. Saranya^{1*}, K. Balamurugan¹ and M. Karuppasamyandian²

¹School of Electrical & Electronics Engineering, SASTRA University, Thanjavur, India; saranee27@gmail.com

²Department of Electrical Engineering, Anna University, Tiruchirapalli, India

Abstract

Congestion Management is major issue in deregulated environment. The goal of congestion management is to alleviate overloads by generator rescheduling and/or load curtailments. Here, congestion is relieved by real power rescheduling employing Artificial Bee Colony algorithm. It comprises of two stages. First stage, Generator Sensitivity Factors (GSF) for the congested line is evaluated. Then, Artificial Bee Colony algorithm is used in the second stage for obtaining minimum values of generator power outputs after rescheduling. The efficacy of this algorithm has been tested on IEEE-30 bus system and four test cases are taken here and programming is developed using MATLAB software.

Keywords: Congestion Management, Contingency Analysis, Deregulation, Generator Sensitivity Factor

1. Introduction

Market participants and Power system researchers faced critical challenges over deregulated power market which encourages the market players to participate and compete in the competitive power market. Paper¹ illustrates the issues dealt on congestion management on deregulated power system and it also emphasis various approaches for congestion management viz auction based congestion management methods, re-dispatch, sensitivity factor based methods and so on. Paper² explains the congestion mitigation measures and also formulates two objective functions. The first function dealt with execution of congestion management by rescheduling of generator real power, hinge on Zone/Cluster method employing Transmission Congestion Distribution Factors and the second objective function focuses on minimizing real power loss. Paper³ illustrates congestion management by generator rescheduling and load curtailments, hinge on simple method in consideration of cost and sensitivity to line currents. Paper⁴ illustrates alleviation of network

overloads by rescheduling generator real power depend on Relative Electrical Distances employing voltage stability margins. Such concepts are well-appropriate for various operations under normal and abnormal conditions. Paper⁵ illustrates the effect of contingency limit by performing contingency analysis at the time of congestion management. Paper⁶ proposes that for transmission congestion management FACTS devices are employed and optimal setting of such devices hinge on Locational Marginal Price and Optimal Power Flow. Paper⁷ illustrates congestion management in transmission grids employing generator redispatch and/or load shedding by multi objective PSO technique together with modified fast decoupled load flow method which is frequency and voltage dependent one. Paper⁸ illustrates the noble method for congestion management which focuses the voltage instability by imposing constraints based on OPF and denies offline transmission capacity limits linked to stability. Paper⁹ explains a method for picking generator used in congestion management and applies PSO as the solution for congestion management problem. Here the

*Author for correspondence

PSO algorithm uses a method different from conventional penalty function method to handle binding constraints. Paper¹⁰ congestion management is managed by rescheduling sensitive generators and load shedding using PSO and uses generator sensitivity factors to pick up the generator for redispatch. This paper also emphasis load-side participation via load shedding.

This paper employs Artificial Bee Colony (ABC) algorithm as an optimization tool to alleviate network overloads in deregulated environment by means of real power generation rescheduling. The efficacy of this algorithm has been tested on IEEE-30 bus system. And the results of ABC method are compared with Real coded genetic algorithm and Simulated annealing algorithm which proves the capability of former method.

2. Congestion Management in Deregulated Environment

In electricity restructuring the major difficulties associated with transmission networks which endanger system security. Power production and Power demand patterns from competitive bidding under restructured environment which will be seen more and results overload in transportation lines. Congestion in power system happens when one or more constraints, such as physical limits like voltage or thermal limits or specified limits are violated in the normal state or in any contingency cases in the list of specified contingencies. It is a non-convex optimization problem with more number of constraints. Mathematical methods fails to solve such problems since it suffer from local optimality problem. Hence an effective control measure is mandatory to mitigate congestion. Evolutionary algorithm is thus applied to get global optimal solution¹¹. Evolutionary algorithm include Artificial Bee Colony algorithm (ABC), Real Coded Genetic Algorithm (RCGA), Particle Swarm Optimization (PSO), Ant Colony Optimization (ACO), Cuckoo Search algorithm (CS), Harmony Search algorithm (HS), Shuffled Frog Leaping algorithm (SFLP), Simulated Annealing algorithms (SA) and so on. These methods adopt the principle of 'survival of the fittest', iteratively to achieve optimal solution in the vicinity. In short, Congestion management is the process which can be taken to avoid and alleviate congestion in order to maintain the system secure and reliable.

Various approaches are being proposed to mitigate congestion in the power system network congestion

management schemes are categorized based on economic factors. They are Cost free means and Non-cost free means. Out ageing of congested lines, transformers taps/phase shifters operation, and employment of FACTS devices particularly series devices comes under cost free means. These methods uses some benchmarks to set aside the transmission capacity and also these methods are pretend to offer some sort of arbitrariness as they do not accord towards efficient cost of congested line. Non cost free means includes generation redispatch and load curtailments. These methods hold good as they contribute economic efficiency¹². This paper deals congestion problem by rescheduling the real power of generators using ABC algorithm. The generators participates in the rescheduling process are picked based on Generator Sensitivity Factors (GSF) values.

3. Artificial Bee Colony Algorithm

3.1 Introduction

ABC algorithm is the most promising method applied to figure out non-smooth optimization problems in power systems. Artificial bee colony comprises of different species of bees: Employee bees, Onlookers, and Scout bees. The number of food sources around the hive is equal to number of employed bees. Exchange of information among bees related to quality of food sources taken place in the dancing area. The dance performed in this dancing floor is named as *Waggle Dance*.

3.2 Control Parameters

The control parameters of ABC algorithm are given below:

NP – Population Number.

Food number – $NP/2$ (Number of food sources equal to half of the colony size).

Limit – Employed bee abandons a food source if it is not improved through limit trials.

Max Cycle – A Stopping Criterion (Number of Cycle for foraging).

3.3 Working of the Algorithm

- Initialize colony population.

Scout Bee Phase

- Scout bee chooses the food sources in a random fashion around the hive.

Employee Bee Phase

- Employee bee estimates the *Fitness* value from the food sources.
- Considers the optimum food source as Global minimum.
- Checks surrounding locations for any other optimum food source.
- The employee bee visits its neighborhood to check for better food source.
- Compare the *Fitness* value of the latest to the latter if it is better, then consider it as optimum or else retain the old one.

Onlooker Bee Phase

- Onlookers estimates Food source Probability and changes the food source position.

$$V_{mn} = x_{ln} + \phi_{mn}(x_{mn} - x_{ln})$$
Where $l = \{1, 2, \dots, N\}$ and $n = \{1, 2, \dots, D\}$ and ϕ_{mn} is a random number between $[0, 1]$.
- More numbers of onlookers are appointed to high fitness sources and lesser ones to small fitness source depending upon the above information.
- After certain trials, abort the unimproved food source and new food source (x_{mn}) is generated by the scout bee.

$$X_{mn} = x_{n(\min)} + \text{rand}(0, 1) * (x_{n(\max)} - x_{n(\min)})$$
Where $x_{n(\min)}$ and $x_{n(\max)}$ are the lower and upper bounds of the parameter to be optimized.
- Repeat the procedure above until the convergence is reached.
- End Process.

4. Mathematical Formulation

4.1 Problem Formulation

The main aim of congestion management is taking up of the adequate control actions in order eliminate overloads in the system by generation redispatch. The objective function of problem is formulated as in equation (4.1)

$$F = \sum_{k \in Ng} (C_k^u \cdot \Delta P_{Gk}^u + C_k^d \cdot \Delta P_{Gk}^d) \frac{\$}{hr} \quad (4.1)$$

Subjected to (4.2) to (4.11)

Equality Constraints

$$P_{Gi} - P_{Di} = V_i \sum_{j \in N_i} V_j (G_{ij} \cos \theta_{ij} + B_{ij} \sin \theta_{ij}) \quad i=1, 2, \dots, NB \quad (4.2)$$

$$Q_{Gi} - Q_{Di} = V_i \sum_{j \in N_i} V_j (G_{ij} \sin \theta_{ij} - B_{ij} \cos \theta_{ij}) \quad i=1, 2, \dots, NB \quad (4.3)$$

$$P_{Gk} = P_{Gk}^C + \Delta P_{Gk}^u - \Delta P_{Gk}^d \quad k=1, 2, \dots, g \quad (4.4)$$

$$P_{Dj} = P_{Dj}^C \quad j=1, 2, \dots, Nd \quad (4.5)$$

Inequality Constraints

$$P_{Gk}^{\min} \leq P_{Gk} \leq P_{Gk}^{\max} \quad \forall k \in Ng \quad (4.6)$$

$$Q_{Gk}^{\min} \leq Q_{Gk} \leq Q_{Gk}^{\max} \quad \forall k \in Ng \quad (4.7)$$

$$\Delta P_{Gk}^{\min} \leq \Delta P_{Gk} \leq \Delta P_{Gk}^{\max} \quad (4.8)$$

$$\Delta P_{Gk}^u \geq 0; \Delta P_{Gk}^d \geq 0 \quad (4.9)$$

Security Constraints

$$P_{ij} \leq P_{ij}^{\max} \quad (4.10)$$

$$V_i^{\min} \leq V_i \leq V_i^{\max} \quad i \in NL \quad (4.11)$$

Where

P_{Gk}^C real power generation of generator

k subject to market clearing

P_{Dj}^C real power consumption of generator

k subject to market clearing

P_{Gk} real power produced by k th generator

P_{Dj} real power consumed by k th generator

NB total number of buses

N_g total number of generator

P_{ij} active power flow

$P_{ij}^{\max}$ maximum power flow limit

NL total number of loads

$P_{Gk}^{\min}, P_{Gk}^{\max}$ lower and upper bounds of generator active power

$Q_{Gk}^{\min}, Q_{Gk}^{\max}$ lower and upper bounds of generator reactive power

4.2 Determination of Generator Sensitivity Values

The Generator Sensitivity (GS) indicates the change of active power flow in the line k connected between the buses i and j due to change in active power generation of

the generator g . The GS values of g th generator on the line linked between buses i and j in the equation (4.12)

$$GS_g = \frac{\Delta P_{ij}}{\Delta P_{Gg}} = \frac{\partial P_{ij}}{\partial \theta_i} \cdot \frac{\partial \theta_i}{\partial P_{Gg}} + \frac{\partial P_{ji}}{\partial \theta_j} \cdot \frac{\partial \theta_j}{\partial P_{Gg}} \quad (4.12)$$

Generator which have strongest and non-uniform flow of GS values for the congested line power flow are taken to reschedule the output power to mitigate the congestion in the transmission line.

5. Results and Interpretations

The test bus system taken is IEEE 30 bus system and the data's are from¹³. IEEE 30 bus system comprises of six generators, twenty one loads and forty one lines. The PQ bus voltages are managed between 0.9 and 1.1 p.u. Price bids given by GENCOS for congestion management is given in¹¹.

First, N-1 Contingency analysis is implemented. From this analysis we can find the severe outage cases. Test cases considered below are taken for simulation and for each cases Newton Raphson power flow is carried out and information about the congested line is given in Table 1

Case A: disconnect the line 2-5 and raise the load at buses 2, 3, 4 and 5 by 35%

i.e. Load factor = 1.35

Case B: Interrupt the line 1-3 and raise the load at bus 19 by 130% i.e.

Load factor = 2.3

Case C: disconnect the line 3-4 and increase load by 250% at bus 2

i.e. Load factor= 3.5

Case D: disconnect the line 1-2 and all load bus loads are raised by 30%, LF=1.3

The GS values of all the four test cases are given in the Table 2

The Generator Sensitivity values of all six generators are approximately same since system is being very small. It shows that all sensitivities value are negative this indicates the increase in power production. These values of generators shows almost equal influence on congested lines which necessitates that all generator buses are selected for rescheduling.

Figure 1 depicts the power flow condition for case A during congestion and after congestion.

The increase and decrease of change in generator active power to relieve overloads for all the cases is given in Table 3. The problem is solved for twenty runs and finest solutions are tabulated.

Figure 1a, 1b, 1c and 1d displays the real power adjustments of generators needed to mitigate congestion.

Table 4 shows the power flow condition for all the four cases during and after congestion.

Table 5 depicts the total cost subjected to congestion management. From this table, it is clear that ABC algorithm is efficient and it gives economical solutions in comparison with RCGA and SA algorithms since it have advantageous in terms of accuracy and fast convergence.

6. Conclusion

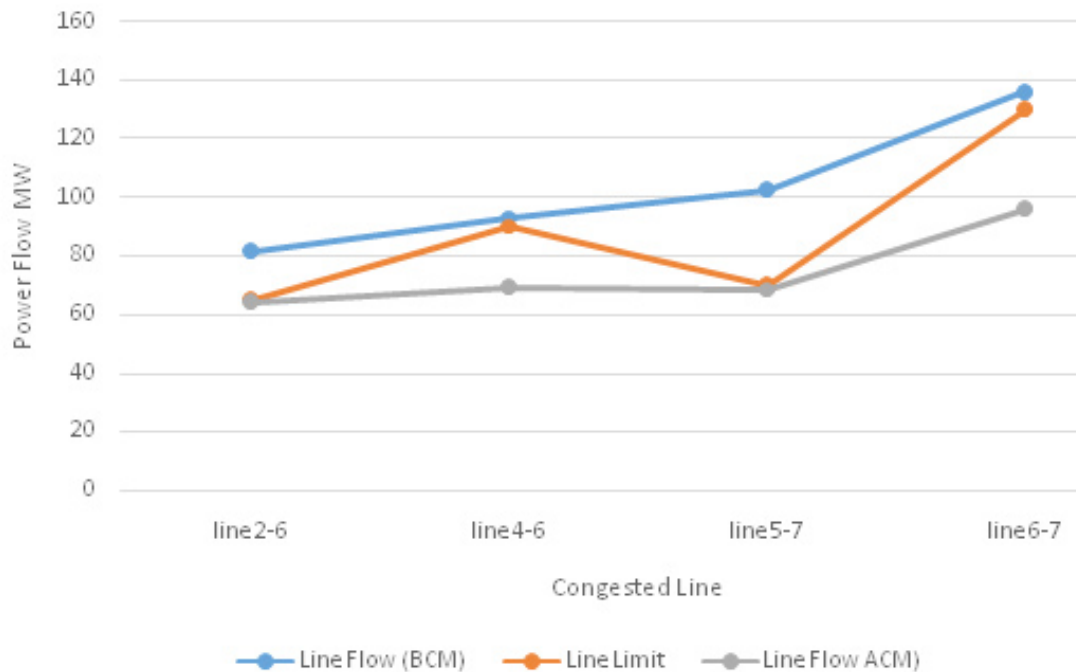
This paper illustrates, an optimal congestion management by generation re-dispatch in verge of power system restructuring using ABC algorithm tested on IEEE 30 bus test system. ABC algorithm would be effective tool

Table 1. Line flow results

Cases	No. of Lines Get overloaded	Congested Lines	Line Limit (Mw)	Magnitude of Power violations (Mw)	Total Power Violation (Mw)
A	4	2-6	65	16.27	58.026
		4-6	90	2.76	
		5-7	70	32.61	
		6-7	130	6.39	
B	1	1-2	130	25.66	25.88
C	1	1-2	130	66.32	70.241
D	3	1-3	130	133.64	280.605
		3-4	130	102.24	
		4-6	90	44.64	

Table 2. GS values for the test cases

Test Cases	No. of Lines Congested	Congested Lines	G1	G2	G5	G8	G11	G13
A	4	2-6						
		4-6	0	-0.5517	-0.5350	-0.4414	-0.4349	-0.4102
		5-7						
		6-7						
B	1	1-2	0	-0.6681	-0.7168	-0.6802	-0.6507	-0.5583
C	1	1-2	0	-0.6806	-0.7297	-0.7794	-0.6596	-0.7159
D	3	1-3						
		3-4	0	-4.2158	-4.1170	-3.4016	-3.3437	-3.1245
		4-6						

**Figure 1.** Power flow condition of congested lines - case A.**Table 3.** Control variable setting for corrective actions.

Test Cases	Generator MW adjustment for Congestion Management					
	ΔP_{G1}	ΔP_{G2}	ΔP_{G3}	ΔP_{G4}	ΔP_{G5}	ΔP_{G6}
Case A	16.5598	0	34.5170	0	0	0
Case B	8.5174	24.3320	0	0	0	0
Case C	7.5301	62.4590	0	1.0270	0	0
Case D	8.6771	67.1410	2.3030	22.0640	10.4310	0

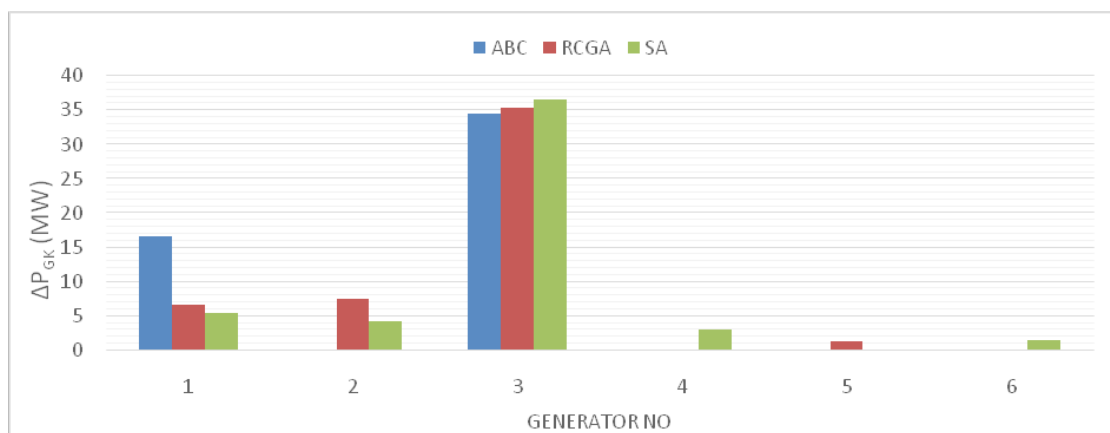


Figure 1a. Case A

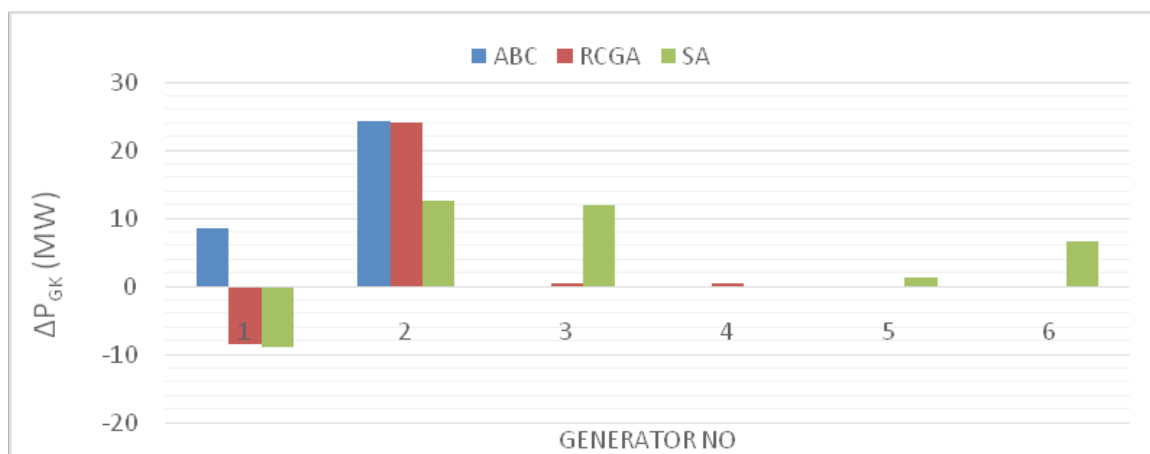


Figure 1b. Case B.

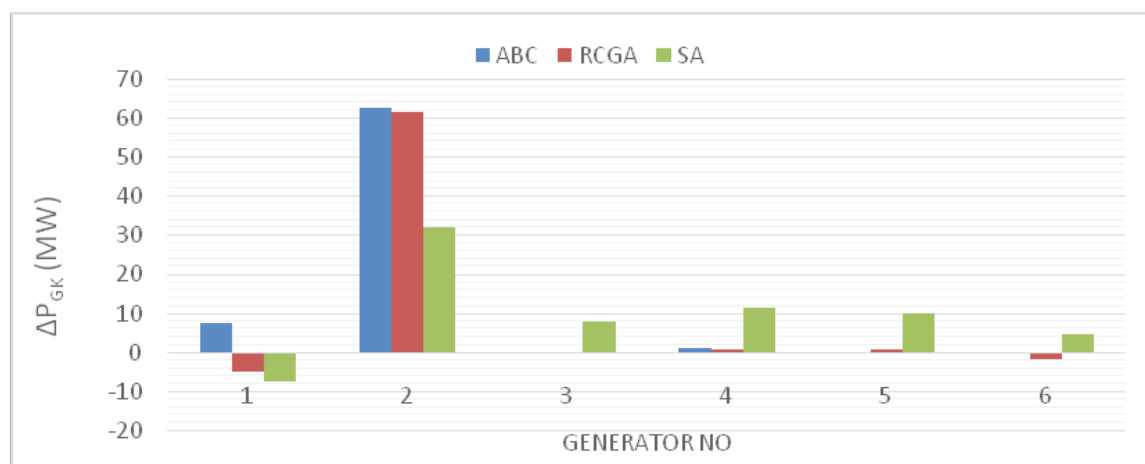


Figure 1c. Case C.

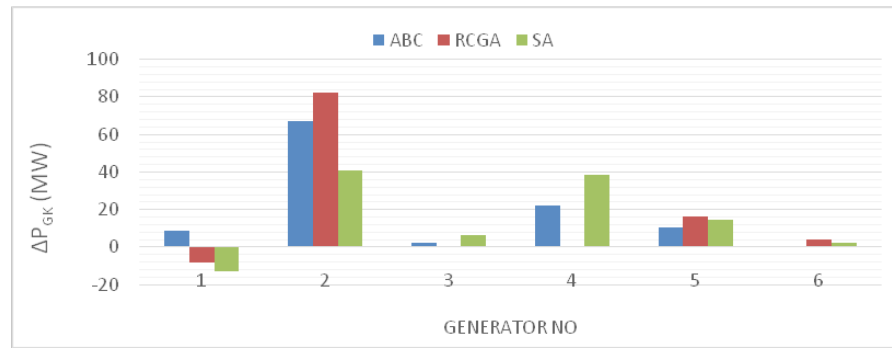


Figure 1d. Case D.

Table 4. Congestion management analysis

Test Cases	Line No	Line Limit	Before Congestion management(MW)	Amount of Power Violation (MW)	After Congestion management(MW)
Case A	2-6	65	81.27	16.27	64
	4-6	90	92.76	2.76	69
	5-7	70	102.61	32.61	68
	6-7	130	136.39	6.39	96
Case B	1-2	130	155.66	25.66	129.95
Case C	1-2	130	196.32	66.32	128.59
Case D	1-3	130	263.64	133.64	129.92
	3-4	130	232.24	102.24	119.99
	4-6	90	134.64	44.64	73.22

Table 5. Congestion cost

Cases	Net Adjustment of Generator for Congestion Management(MW)			Total Cost (\$/hr)	
	ABC	RCGA	SA	ABC	
A	51.7409	1837.8	1918.8	1615.8	
B	32.8494	671.614	892.117	656.032	
C	71.0161	1721.9	2076.5	1399.1	
D	110.6161	2737.2	3672.7	2867.3	

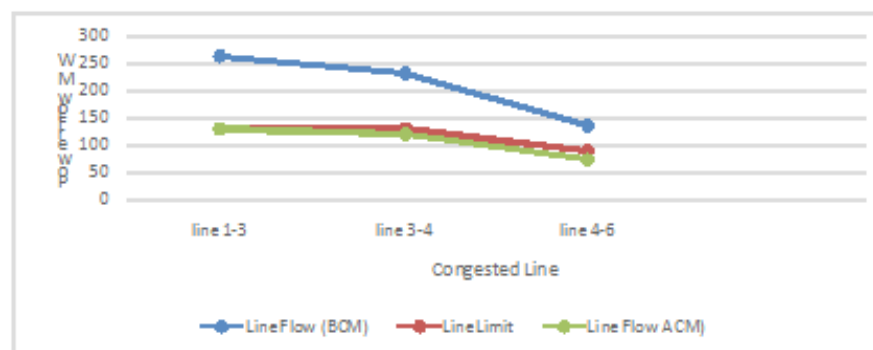


Figure 2. Power flow condition of congested lines - Case D.

in handling transmission line overloads in deregulated environment. It efficiently minimizes re-dispatch cost and also resulting in secure operating condition. Initially contingency analysis is carried out to determine the severe outage case and the power flow results for the test cases are tabulated. Then the Generator Sensitivity Values (GS) is calculated for each case and tabulated. Generators which have strongest and non-uniform flow of GS values are selected for rescheduling process. And also, ABC algorithm is used for obtaining minimum values of generator power outputs after rescheduling which also minimizes re-dispatch cost. Furthermore the congestion is mitigated completely by generator real power rescheduling alone.

7. References

1. Kumar A, Srivastava SC, Singh SN. Congestion management in competitive power market: a Bibliographical survey. *Elect Power Syst Res.* 2005; 76:153–64.
2. Charlesraja S, Venkatesh P. Transmission congestion management in restructured power system. *Proceedings of ICETECT*; 2011. p. 23–28.
3. Talukdar BK, Sinha AK, Mukhopadhyay S, Bose A. A computationally simple method for cost-efficient generation rescheduling and load shedding for congestion management. *Int J Elect Power Energy Syst.* 2005; 27(5):379–88.
4. Yesuratnam G, Thukaram D. Congestion management in open access based on relative electrical distances using voltage stability criteria. *Int J Elect Power Syst Res.* 2007; 77:1608–18.
5. Alomoush MI, Shahidehpur SM. Contingency-constrained congestion management with a minimum number of adjustments in preferred schedules. *Int J Elect Power Energy Syst.* 2000; 22(4):277–90.
6. Joorabian M, Saniei M, Sepahvand H. Optimal locating and sizing of TCPST for Congestion management in Deregulated Electricity markets. *UPEC, 46th International Universities' Power Engineering Conference.* Soest, Germany; 2011 Sep. p. 5–8.
7. Hazra J, Sinha KA. Congestion management using multi objective Particle Swarm Optimization. *IEEE Transaction on Power System.* 2007; 22(4):1726–34.
8. Conejo AJ, Milano F, Bertrand RG. Congestion management ensuring voltage stability. *IEEE Transaction on Power System.* 2006; 21(1):357–64.
9. Dutt S, Singh SP. Optimal rescheduling of generators for congestion management based on particle swarm optimization. *IEEE Transaction on Power System.* 2008; 23:1560–9.
10. Bhattacharjee T, Chakraborty AK. Congestion management in a deregulated power system by rescheduling of sensitive generators and load curtailment using PSO. *IJETAE.* 2012; 2(3):284–9.
11. Balaraman S, Kamaraj N. Congestion management in deregulated power system using real coded genetic algorithm. *Int J Eng Sci Tech.* 2010; 2(11):6681–90.
12. Rajalakshmi L, Suganyadevi MV, Parameswari S. Congestion management in deregulated power system by locating series FACTS devices. *Int J Comput Appl.* 2011; 13(8):19–22.
13. Alsac O, Stott B. Optimal load flow with steady-state security. *IEEE Transaction on Power Application System.* 1974; 93:745–51.