Modified Particle Swarm Optimization approach for Optimal Power Flows with Security Constraints for Indian Practical 75 bus system

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Abstract— *This paper proposes novel particle swarm optimization algorithm for solving optimal power flows with security constraints (line flows and bus voltages). This method uses variable constriction factor approach for the classical Particle Swarm Optimization technique. The variable constriction factor has been identified based on the current error and the initial error. The OPF problem has been considered with the quadratic cost function to realize Optimal Power Flow using the proposed Modified Particle Swarm Optimization algorithm and applied to Indian practical 75 bus system; the results were compared with the Linear Programming approach using Power world simulation software. Simulation results show that proposed approach gives the best solution than earlier reported approaches and their convergence is much quicker compared to the earlier reported literature.*

Keywords—**Particle swarm optimization (PSO), Optimal power flows (OPF), Optimization, Energy Management Systems (EMS), Evolutionary Computation (EC)**

I. INTRODUCTION

The optimal power flow (OPF) has been used as an effective tool in the power system planning and operation for many years. OPF is a very important tool in modern-day Energy Management System (EMS). It plays a crucial role in preserving the power system economy. The OPF problem comprises of a set of equality and inequality constraints was initially formulated in 1962 by Carpentier [1]. The OPF problem is a nonlinear, non-convex, large scale, the static optimization problem with both continuous variables(magnitudes of generator voltages and active powers of generators) and discrete (transformer tap settings and switchable shunt devices) as control variables. Even with out the presence of discrete control variables, the OPF problem [1] is nonconvex due to the presence of the nonlinear (AC) power flow equality constraints. The presence of discrete control variables, such as switchable shunt devices, transformer tap positions further complicates the problem solution.

Numerous optimization techniques have been applied in solving the OPF problem like Quadratic Programming, non-linear programming, Linear Programming, Sequential unconstrained minimization technique, Newton-based methods, interior point methods, Genetic Algorithm, Evolutionary Programming etc.. Heuristic algorithms such as Genetic Algorithms (GA) and Evolutionary programming which have been reported as showing promising results for further research in this direction.

In recent past, a new evolutionary computation technique, called Particle Swarm Optimization (PSO) [2], has contributed quite significantly in the area of optimization for various engineering and other applications. Particle Swarm Optimization (PSO) is one of the most prominent evolutionary computation techniques. In Particle Swarm Optimization, search for an optimal solution is done using a population of particles, each of them represents a candidate solution to the optimization problem. It was developed through the simulation of the flock of birds to search for food optimally through the up gradation of their velocity and position. The PSO technique has been effectively used for the of various power system optimization problems. However, the major problem with PSO is that, it may need many iterations and may get trapped in local optima and may get diverged. Hence, several strategies have been developed to overcome the above-mentioned limitations of PSO, such as modified PSO, attractive and Repulsive PSO. These all were proved to be effective, promoted and boosted the development of MPSO.

For obtaining the best convergence characteristics, various techniques have been reported in the literature. But, the proposed method of variable constriction approach has not been reported in the literature.
This paper is organized as follows: Problem formulation in section II. Modified Particle Swarm Optimization, in section III. Implementation of MPSO for OPF is discussed in section IV. The simulation results are discussed in section V. Finally, brief conclusions are deduced in section VI.

II. PROBLEM FORMULATION OPTIMAL POWER FLOW (OPF)

The OPF problem is a static constrained non-linear optimization problem, the solution of which determines the optimal settings of control variables in a power system network satisfying various constraints. Hence, the problem is to solve a set of non-linear equations describing the optimal solution of power system. It is expressed as

$$\text{Min } F(x,u) \qquad (1)$$
$$\text{Subject to } g(x,u)=0$$
$$h(x,u) \le 0$$

The objective function F is fuel cost of thermal generating units of the test system. g(x,u) is a set of non-linear equality constraints to represent power flow and h(x,u) is a set of non-linear inequality constraints(i.e., bus voltage limits, line MVA limits etc..). Vector x consists of dependent variables and u consists of control variables.

In most of the non-linear optimization problems, the constraints are considered by generalizing the objective function using penalty terms. In this OPF problem, slack bus power PG1, bus voltages VL and line flows Ij are constrained by adding them as penalty terms to objective function. Hence, the problem can be generalized and written as follows.

$$F_T^* = F_{T+}\lambda\left[\sum_{i\in N_L}(I_i - I_{max})^2 + (P_{G1} - P_{G1}^{lim})^2 + \sum_{i\in N_{PQ}}(V_i - V_i^{lim})^2 + \sum_{i\in N_{PV}}\left(Q_{Gi} - Q_{Gi}^{lim}\right)^2 + \sum_{i\in N_{line}}(loss_i)^2\right] \qquad (2)$$

Where λ, the penalty factor, is given as

$$\lambda = \frac{\sum c_i}{Number\ of\ generator\ buses} \qquad (3)$$

V_i^{lim} and P_{G1}^{lim} are defined as

$$V_i^{lim} = \begin{cases} V_i^{max}\ ;\ \mathrm{V_i} > V_i^{max} \\ V_i^{min}\ ;\ \mathrm{V_i} < V_i^{min} \end{cases} (3)\quad P_{G1}^{lim} = \begin{cases} P_{G1}^{max}\ ;\ \mathrm{P_{G1}} > P_{G1}^{max} \\ P_{G1}^{min}\ ;\ \mathrm{P_{G1}} < P_{G1}^{min} \end{cases} \qquad (4)$$

III. MODIFIED PARTICLE SWARM OPTIMIZATION

The inherent rule adhered by the members of birds and fishes in the swarm, enables them to move, synchronize, without colliding, resulting in an amazing choreography which is the basic idea of PSO technique. PSO is a similar Evolutionary computation technique in which, a population of potential solutions to the problem under consideration, is used to probe the search space. The main difference between the other Evolutionary Computation (EC) techniques and Swarm intelligence (SI) techniques is that the other EC techniques make use of genetic operators whereas SI techniques use the physical movements of the individuals in the swarm. PSO is developed through the birds flock simulation in two-dimensional space with their position, x, and velocity, v.

The optimization of the objective function is done iteratively through the bird flocking. In every iteration, every agent knows its best so far, called 'Pbest', which shows the position and velocity information. This information is analogous to the personal experience of each agent. Moreover, each agent knows the best value so far in the group, 'best' among all 'P_{best}'. This information is analogous to the knowledge, as to how the other neighboring agents have performed. Each agent tries to modify its position by considering current positions, current velocities, the individual intelligence (P_{best}), and the group intelligence (G_{best}).

To ensure the best convergence to PSO, Eberhart and Shi indicate that use of constriction factor may be necessary. The modified velocity and position of each particle can be found as follows.

$$v_{d+1} = k_1 \times (\omega \times \mathrm{v_d}) + k_2\left(\mathrm{C_1} \times \mathrm{rand} \times (\mathrm{P_{best}} - \mathrm{X_d}) + \mathrm{C_2} \times \mathrm{rand} \times (\mathrm{G_{best}} - \mathrm{X_d})\right) \qquad (5)$$
$$x_{d+1} = x_d + v_{d+1} \qquad (6)$$

Where d indicates the generation, x_d is the current position of the particle in d_{th} generation, v_d is the velocity of the particle in the d_{th} generation, ω is the inertia weight, C_1 and C_2 are acceleration constants, and k_1 and k_2 are the constriction factors. The constriction factor is been updated by the following equation (7). By making use of this updating, variable constriction factor can be adapted so that the convergence can be achieved quickly.

$$k_1 = k_2 = (\frac{error}{Initial\ error})^{0.009}) \text{ for M PSO} \quad (7)$$

Here, the values of k_1 and k_2 vary in each iteration. The "Initial error" is the highest deviation between the fitness of the agents in first iteration and "error" is the maximum deviation of fitness value between the agents in a n^{th} iteration. In normal PSO the position vector is updated only by velocity vector. Every agent's velocity of must is updated in such a way that it reduces as the agent getting converged and increased as the agent diverges. The multipliers and exponents are selected abruptly in the equation (7) as with these values the algorithm converges quickly.

In PSO, the velocity of the particle is limited by maximum value V_{max}. If V_{max} is too high, particles may overlook good solutions by flying past them. If V_{max} is too small, particles may not cross local optimal solutions. Usually, V_{max} is taken as 10% - 20% of dynamic range and V_{min} is assumed as - V_{max}.

$$V_{max} = \frac{(Max\ position\ limit - Min\ position\ limit)}{10} \quad (8)$$

MPSO flowchart has been shown in Fig.1.

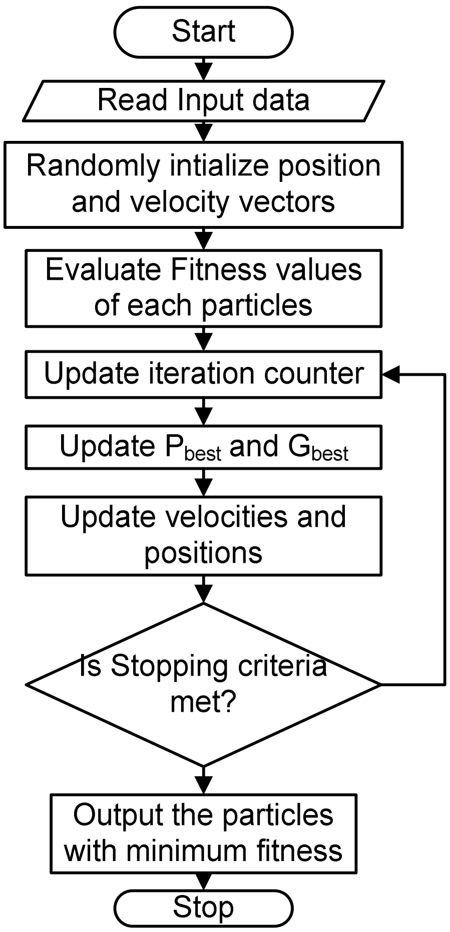

Fig.1 Flow chart of MPSO algorithm

V. RESULTS AND DISCUSSION

The proposed algorithm is implemented in C programming language and executed on Intel Core 2 Duo system with 1GB RAM running on Linux. To assess the performance of the MPSO algorithm, a standard Indian Practical 75 bus system was considered as shown in Fig 2. The table presented below shows a comparison of the results for MPSO with variable constriction factor approach with Linear Programming approach in Power World simulation environment. For the proposed MPSO algorithm c1=0.6, c2=0.4, r1=0.6, r2=0.4 and inertia, ω=0.8 have been considered. The number of particles in the MPSO algorithm has been considered as 25.

Fig 2. Shows the single line diagram of standard IEEE 75 bus system.

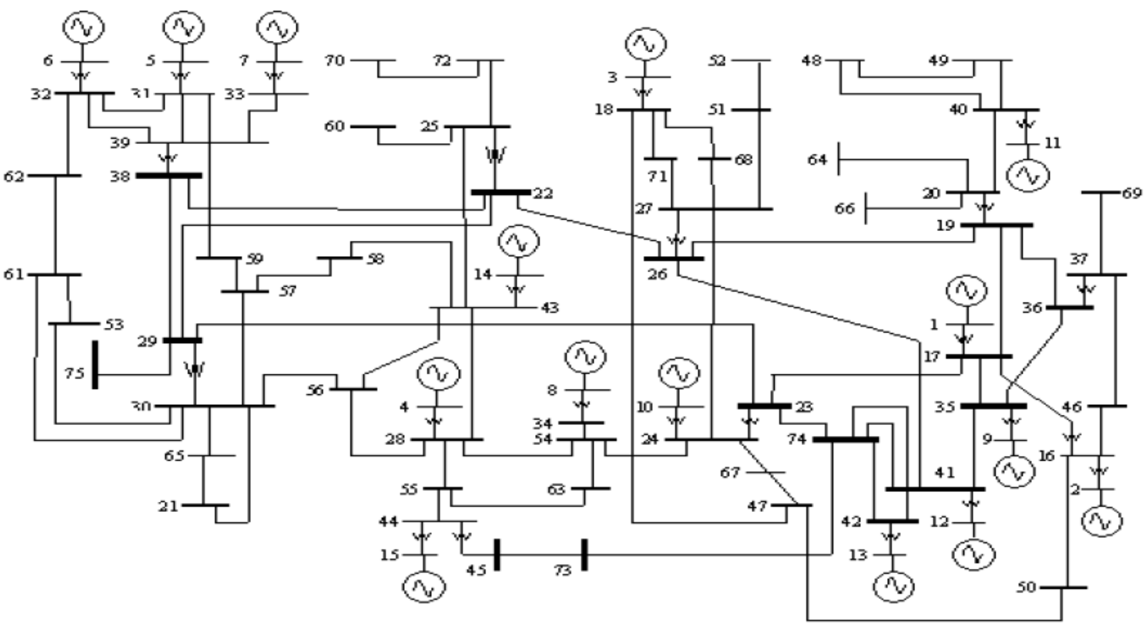

Fig 2. single line diagram of standard IEEE 75 bus system

TABLE 1
GENERATOR DATA WITH QUADRATIC COST FUNCTIONS CONSIDERED FOR INDIAN PRACTICAL 75 BUS SYSTEM.

Generator No.	a_i, $/hr	b_i, $/MW-hr	c_i, $/MW^2-hr
1	459	6.65	0.00074
2	414	7.12	0.0012
3	459	7.17	0.000985
4	561	6.52	0.000715
5	619	6.30	0.0495
6	489	7.09	0.00136
7	589	5.30	0.0032
8	389	6.93	0.00125
9	347	7.04	0.00105
10	510	6.88	0.00081
11	510	6.79	0.00081
12	472	6.28	0.00077
13	483	6.46	0.000745
14	459	5.98	0.00067
15	534	7.10	0.025

TABLE 2

COMPARISON OF RESULTS WITH LP and MPSO FOR OBTAINING OPTIMAL FUEL COST OF INDIAN PRACTICAL 75 BUS SYSTEM

Total System Load = 5568.12 MW

Generator bus No	LP based OPF		MPSO based OPF	
	P_{Gen} MW	Q_{Gen} Mvar	P_{Gen} MW	Q_{Gen} Mvar
1 (slack bus)	684.2	32.36	845.05	39.34
2	293	11.02	282.52	10.23
3	280.00	40.49	279.93	43.45
4	184.92	-0.25	189.87	-0.2
5	25.00	11.15	25	9.23
6	220.00	27.86	219.95	25.34
7	160.00	6.06	160	8.34
8	180.00	36.29	179.96	34.23
9	400.00	130.92	206.59	124.43
10	180.00	18.52	179.96	16.87
11	209.00	52.39	208.95	56.34
12	1150.00	186.69	1121.8	1906.56
13	945079	177.97	999.76	157.65
14	250.00	-11.70	249.94	-12.95
15	554.00	-66.82	553.87	-74.54
Total Generation (MW)	**5715.91**	**-**	**5703.11**	
System Loss (MW)	**147.79**	-	**134.99**	
Fuel cost ($/hr)	**48197.14**	-	**48112.67**	
Iterations	**-**	-	**45**	
CPU time (sec)	**-**	-	**9.5**	

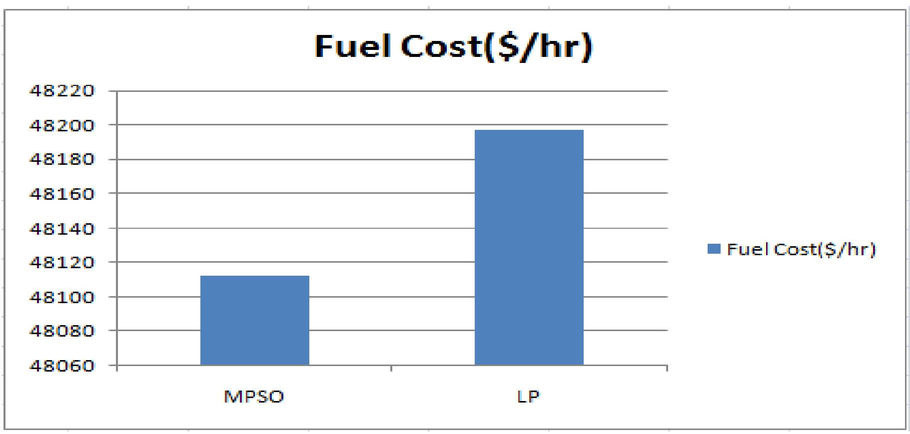

Fig. 3 Fuel cost Comparison graph of Indian practical 75 bus system

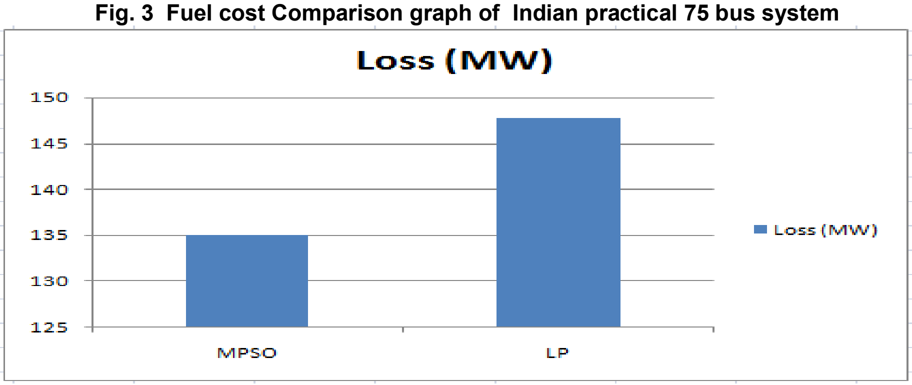

Fig. 4 Loss Comparison graph of Indian practical 75 bus system

VI.CONCLUSION

Based on Variable constriction factor approach, Modified Particle Swarm Optimization Technique has been proposed and developed for solving Optimal power Flow problem (OPF) with security constraints. In recent past, OPF problem has been attempted by several methods in the literacy, but this unique MPSO using variable constriction factor approach found the global or near optimum global point for OPF problem. Indian Practical 75 bus system with quadratic cost function has been tested with the proposed MPSO algorithm and results are compared with the Linear Programming method. From the results, MPSO converges to global optimum with more accuracy and within less time compared to Linear Programming method. The proposed algorithm got converged within 9.5 seconds which is very helpful in real time power system applications to study the condition of the system. Hence, we can say that, the proposed MPSO algorithm is quick and accurate. Most importantly, it is observed from the literature that we have got the best optimal cost with MPSO algorithm. The proposed algorithm can be used in general for any application and also can be used to other power system optimization problems. From the literature, it is observed that, ACOPF has not been approached in proper way for Indian Practical 75 bus system. This results about 75 bus system were quite accurate and are very much useful in the OPF research field.

REFERENCES

1. *H. W. Dommel and W. F. Tinney (1968), Optimal power flow solutions, IEEE Trans. Power App. Syst., 87(10), 1866-1876.*
2. *Bo Yang,Yuping ChenmZunlian Zhao and Qiye Han, "Solving Optimal Power Flow Problems with improved Particle Swarm Optimization",Proceedings of 6th world congress on Intelligent Control and Automation,June 21-23,2006,Dalian,China.*
3. *Sivasubramani.S, Shanti Swarup K, Multiagent Based Particle Swarm Optimization Approach to Economic Dispatch With Security Constraints December27-29'2009, International Conference on Power systems, ,Kharagpur" .*
4. *K.Ravi Kumar, S.Anand and M.Sydulu.: : "Optimal Power Flows with Security Constraints Using Multi Agent based PSO Algorithms by Optimal Placement of Multiple SVCs", International Journal of Computer Applications., Vol. 52-No.10,pp.29–37,2012,ISSN:0975-8887, www.ijcaonline.org.*
5. *J. Nanda, D.P. Kothari, and S.C. Srivastava, "New optimal power dispatch using fletcher's quadratic programming method," IEEE Proc C, pp. 153-161, 1989.*
6. *J. Nanda, and B.R. Narayanan, "Application of genetic algorithm to economic load dispatch with line flow constraints," Int Journal of Electric Power Energy Systems, pp. 723-729, 2002.*
7. *P. Somasundaram, and K. Kuppusamy, "Application of evolutionary programming to security constrained economic dispatch," Electric Power and Energy Systems, pp. 343-351, 2005.*
8. *J. Kennedy, and R. Eberhart, "Particle swarm optimization," Proc IEEE Int Conf Neural Networks, Aust, pp. 1942-1948, 1995.*
9. *R.C. Eberhart, and Y. Shi, "Comparing inertia weights and constriction factors in particle swarm optimization," Proc Congr Evolutionary Computation, pp. 84-88, 2000.*
10. *J. B. Park, K.S. Lee, J.R. Shin, and K.Y. Lee, "A particle swarm optimization for economic dispatch with nonsmooth cost functions," IEEE Trans on Power Systems, pp. 34-42, 2005.*
11. *K.S. Swarup, and P. Rohit Kumar, "A new evolutionary computation technique for economic dispatch with security constraints," Electric Power and Energy Systems, pp. 273-283, 2006.*
12. *M. Wooldridge, An introduction to multiagent system. New York: Wiley, 2002.*
13. *W. Zhong, J. Liu, M. Xue, and L. Jiao, " A multiagent genetic algorithm for global numerical optimization," IEEE Trans on Sys, Man and Cybernatics, pp. 1128-1141, 2004.*
14. *B. Zhao, C.X. Guo, and Y.J. Cao, "A multiagetn-based particle swarm optimzation approach for optimal reactive power dispatch," IEEE Trans on Power Systems, pp. 1070-1078, 2005.*
15. *Y.Wallach, Calculations and programs for power system networks. Englewood Cliffs, NJ: Prentice-Hall, 1986.*
16. *A.Wood. B. Woolenberg, power generation, operation and control, New York: Wiley,1996.*

BIBLIOGRAPHY

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