International Journal of Electrical and Electronics Research ISSN 2348-6988 (online)
Vol. 3, Issue 2, pp: (497-503), Month: April - June 2015, Available at: www.researchpublish.com

Solving the Economic Load Dispatch Problem in Power System with Inequality Constraints Using MPSO

[1]R.Sangeetha, [2]V.Thirumurugan, [3]C.Thulasiammal

[1, 2, 3] AICTE, Anna University- Chennai, The Kavery Engineering College, Salem, India

Abstract: **Modified Particle swarm optimization (MPSO) is applied to allot the active power among the generating stations satisfying the system constraints and minimizing the cost of power generated. The viability of the method is analyzed for its accuracy and rate of convergence. The economic load dispatch problem is solved for six unit system using MPSO for both cases of neglecting and including transmission losses. The optimization technique is constantly evolving to provide better and faster results. The economic load dispatch (ELD) plays a important role in operation of power system to decrease the power consumption and to fulfill the load demand in such a way to minimize the total generation cost and satisfying the equality and inequality constraints.**

Keywords: **Economic Load Dispatch (ELD), generator constraints, Emission constraints, Particle swarm optimization (PSO), Modified particle swarm optimization (MPSO).**

1. INTRODUCTION

With large interconnection of the electric networks, the energy crisis in the world and continuous rise in prices, it is very essential to reduce the running costs of electric energy. A saving in the operation of the power system brings about a significant reduction in the operating cost as well as in the quantity of fuel consumed. The main aim of modern electric power utilities is to provide high-quality reliable power supply to the consumers at the lowest possible cost while operating to meet the limits and constraints imposed on the generating units and environmental considerations. These constraints formulates the economic load dispatch **(ELD)** problem for finding the optimal combination of the output power of all the online generating units that minimizes the total fuel cost, while satisfying an equality constraint and a set of inequality constraints. Traditional algorithms like lambda iteration, base point participation factor, gradient method, and Newton method can solve this ELD problems effectively if and only if the fuel-cost curves of the generating units are piece-wise linear and monotonically increasing . Practically the input to output characteristics of the generating units are highly non-linear, non-smooth and discrete in nature owing to prohibited operating zones, ramp rate limits and multifuel effects. Thus the resultant ELD becomes a challenging non-convex optimization problem, which is difficult to solve using the traditional methods. Methods like dynamic programming, genetic algorithm, evolutionary programming, artificial intelligence, and particle swarm optimization solve non-convex optimization problems efficiently and often achieve a fast and near global optimal solution. Among them MPSO was developed through simulation of a simplified social system, and has been found to be robust in solving continuous non-linear optimization problems. The MPSO technique can generate high-quality solutions within shorter calculation time and stable convergence characteristics.

2. ECONOMIC DISPATCH PROBLEM FORMULATION

A. Basic Economic Dispatch Formulation:

Economic load dispatch is one of the most important problems to be solved in the operation and planning of a power system, the primary concern of an ELD problem is to determine the generated power of all on-line generating units which minimize the total fuel cost as well as minimizing the environmental emission of the system, while satisfying equality and inequality constraints. The ED problem objective function can be formulated mathematically as given in eq. (1) and (2).

F_T=Min $f(F_i(P_i))$……………………….(1)

$f(F_iP_i)=\sum_{i=1}^{n} a_i \times p_i^2 \times b_i \times p_i \times c_i$…………....(2)

Where, is the objective function, ai, bi and ci are the cost coefficients. n is the number of generating unit.

B. Constraints:

A. system constraints:

Equality constraints:

The equality constraints are the basic load flow equations of active and reactive power.

$$\sum_{i=1}^{N} P_i = P_D + P_L = 0 \quad \ldots\ldots(3)$$

$P_L=\sum_{j=0}^{n} P_i B_{ij} P_j$....................................(4)

Where, PD , PL is the total system demand & line loss respectively. Bij Line loss elements.

Inequality constraints:

Generator Limits

Generation output of each unit should lie between maximum and minimum limits as given in (5)

$P_{min} \le P \le P_{max}$…….(5)

Where, Pi is the output power of ith generator.

B. Cost function:

The generated real power PGi has a major real power generation can be raised by increasing the prime mover torque which requires an increased expenditure of fuel. The reactive generations Q_{Gi} do not have any significant influence on Ci because they are controlled by controlling the field excitation. The individual production cost Ci of generator units is therefore for all practical purposes considered a function only of P_{Gi} , and for the overall production cost C, we thus have

$\sum_{i=1}^{N} C_i(P_{Gi})$…………………………(6)

Let C_i represents the cost function.

***C. Emission coefficients**:* The Emission cost (Kg/h) of the i^{th} generating unit is described as in eq. (7).

$F(E_i(P_i))= \sum_{i=1}^{n} d_i \times p_i^2 + e_i \times p_i + f_i$..............(7)

Where, d_i, e_i and f_i are the emission co-efficient of the i^{th} unit.

3. PROBLEM FORMULATION

The objective of the economic load dispatch problem is to minimize the total fuel cost. MPSO is initialized with a group of random particles (solutions) and then searches for optima by updating generations. In every iteration, each particle is updated by following two "best" values. The first one is the best solution (fitness) it has achieved so far. This value is called pbest. Another "best" value that is tracked by the particle swarm optimizer is the best value, obtained so far by any particle in the population. This best value is a global best and called g-best. This best value is a global best and called g-best. After finding the two best values, the particle updates its velocity and positions according to the following equations.[2]

$$V_i^{(u+1)} = w * V_i^{(u)} + C_1 * rand(\,)*(pbest_i - P_i^{(u)}) + C_2 * rand(\,)*(gbest_i - P_i^{(u)})$$

$$P_i^{(u+1)} = P_i^{(u)} + V_i^{(u+1)}$$

In the above equation,The term rand ( )*(pbest$_i$ - $P_i^{(u)}$) is called particle memory influence.

The term rand ( )*(gbest$_i$ -$P_i^{(u)}$) is called swarm influence. In the above equation, C1 generally has a range (1.5,2) which is called as the self-confidence range and C2 generally has a range (2, 2.5) which is known as the swarm range. $V_i^{(t)}$ which is the velocity of the ith particle at iteration 'i' should lie in the pre-specified range (Vmin,Vmax). The parameter Vmax determines the resolution with which regions are to be searched between the present position and the target position. If Vmax is too high, particles may fly past good solutions. If Vmax is too small particles may not explore sufficiently beyond local solutions. Vmax is often set at 10-20% of the dynamic range on each dimension.

The constants C1 and C2 pull each particle towards pbest and gbest positions. Low values allow particles to roam far from the target regions before being tugged back. On the other hand, high values result in abrupt movement towards, or past, target regions. Hence the acceleration constants C1 and C2 are often set to be 2.0 according to past experiences.

The inertia constant can be either implemented as a fixed value or can be dynamically changing. This parameter controls the exploration of the search space. Suitable selection of inertia weight 'ω' provides a balance between global and local explorations, thus requiring less iteration on average to find a sufficiently optimal solution. As originally developed, ω often decreases linearly from about 0.9 to 0.4 during a run. In general, the inertia weight *w* is set according to the following equation,

$$W = W_{max} * \frac{W_{max} - W_{min}}{ITER_{max}} * ITER$$

Where W -is the inertia weighting factor

W_{max} - maximum value of weighting factor

W_{min} - minimum value of weighting factor

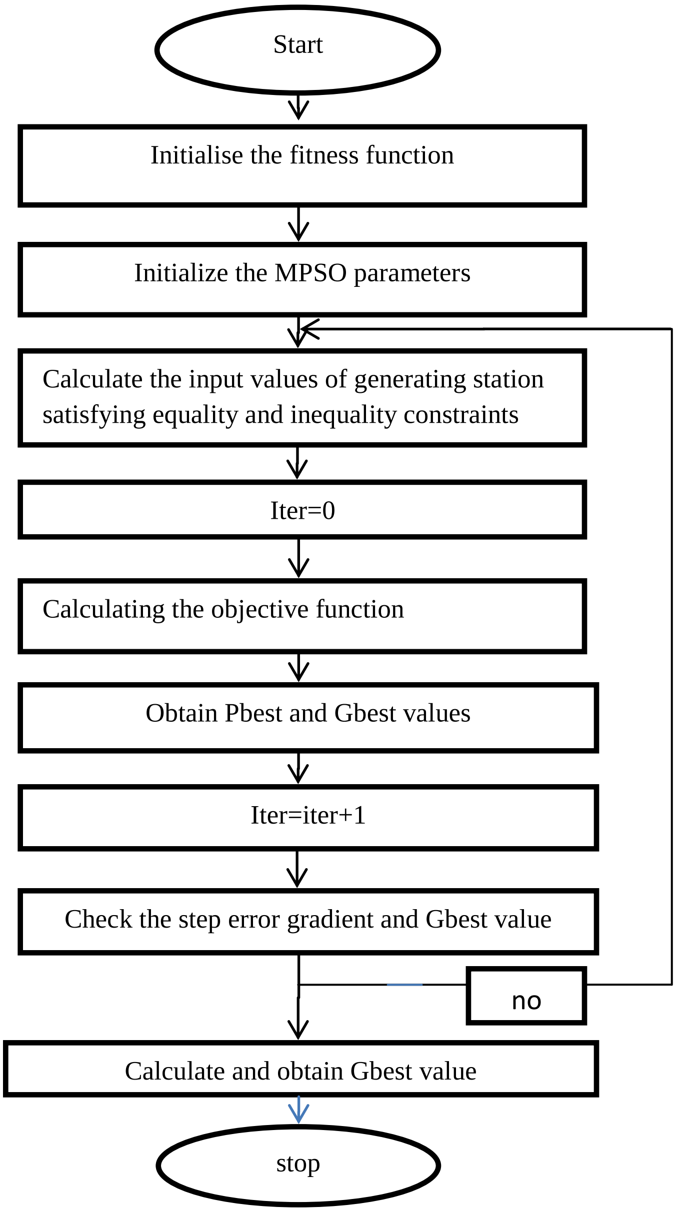
ITER – Current iteration number

$ITER_{max}$-Maximum iteration number.

4. MPSO METHOD TO ECONOMIC LOAD DISPATCH

1. Initialize the Fitness Function ie. Total cost function from the individual cost function of the various generating stations.
2. Initialize the MPSO parameters Population size, C1, C2, W_{MAX}, W_{MIN}, error gradient etc.
3. Input the Fuel cost Functions, MW limits of the generating stations along with the B-coefficient matrix and the total power demand.
4. At the first step of the execution of the program a large no(equal to the population size) of vectors of active power satisfying the MW limits are randomly allocated.
5. For each vector of active power the value of the fitness function is calculated. All values obtained in an iteration are compared to obtain Pbest. At each iteration all values of the whole population till then are compared to obtain the Gbest. At each step these values are updated.
6. At each step error gradient is checked and the value of Gbest is plotted till it comes within the pre-specified range.
7. This final value of Gbest is the minimum cost and the active power vector represents the economic load dispatch solution.

5. FLOW CHART OF MPSO METHOD



Advantages of MPSO:

1. It only requires a fitness function to measure the 'quality' of a solution instead of complex mathematical operation like gradient or matrix inversion. This reduces the computational complexity and relieves some of the restrictions that are usually imposed on the objective function like differentiability, continuity, or convexity.
2. It is less sensitive to a good initial solution since it is a population-based method.
3. It can be easily incorporated with other optimization tools to form hybrid ones.
4. It has the ability to escape local minima since it follows probabilistic transition rules
5. It can be easily programmed and modified with basic mathematical and logical operations
6. It is in-expensive in terms of computation time and memory.
7. It requires less parameter tuning.

6. RESULTS

Table I Optimal Scheduling of Generators of a Six-unit system by MPSO Method (Loss neglected case).

Sl No.	POWER DEMAND (MW)	P1(MW)	P2(MW)	P3(MW)	P4(MW)	P5(MW)	P6(MW)	TOTAL FUEL COST (Rs/hr)
1	800	28.7401 3	10.00002 133	123.258 8	126.933	260.04	251.028	40675. 9682
2	900	32.5163 4594	10.79475 825	143.674 6427	142.986 8715	287.1309 084	282.896 4732	45464. 08097
3	1000	36.1148 8234	15.98564 928	163.134 7857	158.455 3349	312.9788 852	313.330 4625	50363. 69128

Table II Comparison of results between Conventional method and MPSO method for Six-unit system (Loss Neglected Case).

SI.No.	Power Demand (MW)	Conventional Method (Rs/Hr)	MPSO Method (Rs/Hr)
1	800	40675.97	40675.9682
2	900	45464.08	45464.08097
3	1000	50363.69	50363.69128

Table III C. Optimal Scheduling of Generators of a Six-unit system by MPSO Method (Loss included case).

Sl N O	Power Dema Nd (MW)	P1 (MW)	P2 (MW)	P3 (MW)	P4 (MW)	P5 (MW)	P6 (MW)	TOTAL FUEL COST (Rs/hr)	Loss, PL (MW)
1	800	32.597 68442	14.488 45674	141.56 64943	136.00 37228	257.68 48641	242.98 92988	41896.62871	25.33052 121
2	900	36.868 89028	21.082 89623	163.96 47439	153.22 07934	284.11 19384	272.73 71403	47045.15634	31.98640 267
3	1100	48.048 21465	38.257 27999	222.14 71275	198.39 31315	325	315	57870.36512	46.84575 365

Table IV D. Comparison of results between Conventional Method and MPSO method of a Six- unit system (Loss included Case).

Sl No.	Power Demand (MW)	Conventional Method (Rs/Hr)	MPSO Method (Rs/Hr)
1	800	41896.63	41896.62871
2	900	47045.16	47045.15634
3	1100	57871.60	57870.36512

7. CONCLUSION

MPSO method was employed to solve the ELD problem for six unit system. The MPSO algorithm showed superior features including high quality solution, stable convergence characteristics. The solution was close to that of the conventional method but tends to give better solution in case of higher order systems. The comparison of results for the test cases of six unit system clearly shows that the proposed method is indeed capable of obtaining higher quality solution efficiently for higher degree ELD problems. The convergence tends to be improving as the system complexity increases. Thus solution for higher order systems can be obtained in much less time duration than the conventional method. The reliability of the proposed algorithm for different runs of the program is pretty good, which shows that irrespective of the run of the program it is capable of obtaining same result for the problem. Many non-linear characteristics of the generators can be handled efficiently by the method. The MPSO technique employed uses a inertia weight factor for faster convergence. The inertia weight is taken as a dynamically decreasing value from Wmax to Wmin at and beyond ITER max.

REFERENCES

[1] M.E. EI- hawary & G.S. Christensen, "Optimal economic operatiom of Electrical power system," New York,Academic, 1979.

[2] S. Hemamalini, and Sishaj P Simon, "Short term hydro thermal scheduling with bilateral traction via bundle method," International Journal of Electrical power & Energy system, 29(5), pp-387-396, 2007.

[3] Martinez Luis Jose, Lora Trancoso Alicia & Santos Riquelme Jesus,"Short term hydrothermal coordination based on interior point nonlinear programming and genetic Algorithm,"IEEE porto power Tech Confrence, 2001.

[4] M. Gar CW, Aganagic JG,Tony Meding Jose B & Reeves S,"Experience with mixed integer linear programming based approach on short term hydrothermal scheduling," IEEE transaction on power system, 16(4), pp.743-749, 2001.

[5] K.Ng and G.Shelbe, " Direct load control –a profit-based load management using linear programming," IEEE transaction on power system,vol.13,no.2, pp.688-694, 1998.

[6] Shi CC, Chun HC, Fomg IK & Lah PB.," Hydroelectric generation scheduling with an effective differential dynamic programming algorithm," IEEE transaction on power system 5(3), pp.737-743, 1990.

[7] Erion Finardi C, silva Edson LD, & Laudia sagastizabal CV., "Solving the unit commitment problem of hydropower plants via Lagrangian relaxation and sequential quadratic programming," Computaional & Applied Mathematics 24(3), 2005.

[8] Tkayuki S & Kamu W., "Lagrangian relaxation method for price based unit commitment problem," Engineering optimization taylor Francis, pp.36-41, 2004.

[9] D.I. sun, B.Ashley,B.Brewer,A.Hughes and W.F. Tinney, "Optimal power flow by Newton Aproach," IEEE transaction on power system, vol.103, pp.2864-2880, 1984.

[10] A.Santos and G.R. da Costa, "Optimal power flow by Newtons method applied to an augmented Lagrangian function," IEE proceedings generation, Transmission & distribution, vol.142,no.1, pp.33-36, 1989.

[11] Nidhul Sinha, R.Chakrabarti & P.K. Chattopadhyay, "Evolutionary programming techniques for Economic load Dispatch," IEEE transactions on Evolutionary Computation, Vol.7 No1, pp.83-94, 2003.

[12] K.P. wong & J. yuryevich, "Evolutionary based algorithm for environmentally constraints economic dispatch," IEEE transaction on power system , vol.13,no.2, pp.301-306, 1998.

[13] W.M. Lin,F.S. Cheng & M.T. Tsay, "An improved Tabu search for economic dispatch with multiple minima," IEEE transaction on power system , vol.17,no.2, pp.108-112, 2002.

[14] J.S. Al-Sumait, A.K. Al-Othman & J.K. Sykulski, "Application of pattern search method to power system valve point economic load dispatch," Elect. Power energy system, vol.29,no.10, pp.720-730, 2007.

[15] Tarek Bouktir, Linda Slimani & M.Belkacemi, "A genetic algorithm for solving for the optimal power flow problem," Leonardo journal of sciences, Issue-4,pp.44-58,2004.

[16] K. Vaisakh & L.R. Srinivas, "Differential approach for optimal power flow solutions," Journals of theoretical and applied information Technology, pp. 261-268, 2005.

[17] Boumediene Allaoua & Abedellah Laoufi, "Optimal power flow solution Unsing ant manners for electrical network," Advance in Electrical & Computer engg.," Vol.9, pp.34-40, 2009.

[18] L.L. Lai & Mata Prasad, "Application of ANN to economic load dispatch," proceeding of 4th international conference on Advance in power system control, Operation and management, APSCOM-97, Hong-Kong, pp.707-711, nov-1997.

[19] J.Kennedy & R.C. Eberhart, "Particle Swarm Optimization," proceeding of IEEE international conference on Neural networks , Vol.4, pp. 1942-1948,1995.

[20] K.Satish kumar, "Economic load dispatch with emission constraints using various pso algorithm," wseas, vol 9, pp. 598-608, sep- 2008.

[21] Adel Ali Abou EL-Ela & Ragab Abdel-Aziz EI-Sehiemy, "Optimized generation costs using modified particle Swarm optimization version,"Wseas transactions on power systems, pp.225-232, Oct-2007.

[22] R.C. Eberhart & Y. Shi, " Comparing inertia weights and constriction factor in PSO," in proc. Congr. Evolutionary computation, vol.1, pp.84-88, 2008.

[23] Hao Gao & Wenbo Xu, " A new particle swarm algorithm and its globally convergent modifications," IEEE transaction on sytem, man and cybernetics-part B, Vol. 41, No. 5, oct. 2011, pp 1334-1351.

[24] Phan Tu Vu, Dinhlungle & Joef, "A Novel weight-Improved Particle swarm optimization algorithm for optimal power flow and economic load dispatch problem," IEEE Transaction , pp.1-7, 2010.