OPTIMIZATION OF ECONOMIC LOAD DISPATCH PROBLEM BY USING TABU SEARCH ALGORITHM

Dr.Vijay Kumar Joshi[1]

Abstract: Fuel cost and the level of satisfaction of demand is the important factor in electricity power system. Today power dispatching includes the generation, monitoring of load, interchanging and transmission to provide balance in load supply and losses. Economic load dispatch is the scheduling of power generators with respect to the load to minimize the total cost of transmission and operational costs of generating units within the constraints. The main objective of the ELD is to assign the total transmission loss and total load demand among power units while satisfying the operational constraints simultaneously. In this paper, Tabu Search Algorithm is used to solve Economic Dispatch load (ELD) problem. The efficiency of the proposed method is compared with other traditional techniques. Result proves that the proposed algorithm provides the precise solutions with fast convergence time; it also shows the potential to be practiced with other electric power system problems.
Keywords: Economic load dispatch, optimization, metheuristic, Tabu Search

I. INTRODUCTION

The economical and effective operation of electric power generation system always occupies an major occupation in power industry. With increase in demand, electric power grids and energy crises across the world, the prices of fuel also rise continuously. Economic dispatch is the significant constituent of electric power systems. The economic load dispatch is the optimization problem in order to search the optimum economic schedule of the generation plants while satisfying the inequality and equality constraints in order to meet the load demands. The ELD problem mainly deals with two problems i.e first is pre dispatching and other is online dispatch of units to meet the dynamic requirements of power system in order to minimize the cost of system. The problem is evaluated as the reducing of cost of fuel in power system with satisfied operational constraints. In order to solve ELD problem many conventional techniques like dynamic programming, non-linear programming, gradient method, lambda iteration method and linear programming were used in past. In this paper, tabu search algorithm is proposed to solve the ELD problem. In addition, the proposed algorithm is utilized to verify the efficiency.

II. LITERATURE SURVEY

L.H. Wua, Y.N. Wanga, X.F. Yuana, S.W. Zhoub [1] represent the EED problem as a nonlinear constrained multi objective problem with objectives of fuel cost, emission and system loss. The future MODE approach adopts an external elitist archive to retain non-dominated a multi-objective differential evolution (MODE) algorithm for environmental/economic power dispatch (EED) problem.

Liang. [2] proposed a dynamic programming (DP) technique used to solve economic dispatch including transmission losses. But these classical methods are totally based on assumption values and do not follow converging solution for inappropriate values selected.

Hong-Tzer Yang Member, IEEE Pai-Chum Yang Ching-Lien Huang Member, IEEE [3] develops an algorithm based on evolutionary programming for general economic dispatch (ED) algorithm for units with non-smooth fuel cost functions.

Tarek, Linda S [5] presents a simple genetic algorithm solution to solve optimal power flow problem of large distribution systems. The aim is to minimize the fuel cost and keep the power outputs of generators, bus voltages, shunt capacitors/reactors and transformers tap-setting in their secure limits.

Palanichamy and Shrikrishna K., [10] discussed Simple algorithm for economic power dispatch for optimizing the problem while satisfying a set of system operating on strains, including constraints dictated by the electric network

---

[1] *Proessor & Head of Department,LCET Katanikalan*

Dhillon J.S., Parti S.C. and Kothari [12] formulated the problem as multi objective one. They considered objectives such as operating cost, minimal emission and minimum transmission losses in thermal power dispatch systems, considering uncertainties and inaccuracies in system data.

Happ [13] reviewed the progress of optimal dispatch, also called economic load dispatch since its inception to the present in chronological sequence. The classic single area as well as multi area cased is summarized, and the important theoretical work in optimal load flows suggested to date reviewed.

Chen Po- Hung & chan hong [8] this paper proposed a genetic approach for solving the economic dispatch problem in large scale system. A new coding technique for solving the ELD solution is developed in this paper. It is faster than lambda iteration method.

Bouzeboudja Hamid, Chaker Abdelkader and Alali Ahmed [15] proposed about the economic load dispatch using the real coded genetic algorithm (RCGA).

Ongsakul W. [16] proposed a genetic algorithm based on merit order loading solution to solve dynamic economic dispatch problem for combined cycle units with linear decreasing & decreasing incremental cost function with different migration strategies, the proposed method compromises the solution quality and speed up upper bounds for the best performance.

Zhang Zhisheng [17] state that Quantum-behaved particle swarm optimization algorithm is firstly used in economic load dispatch of power system and is the integration of particle swarm optimization algorithm and quantum computing theory.

III. ELD PROBLEM FORMULATION

The ELD problem assume as an complex optimization problem of electric power systems for the minimization of the total fuel rate of all generating units so as to meet the load demand while honoring the equality, inequality and other constraints. Economic dispatch reduces fuel cost and emissions as high-efficiency units frequently expel lower efficiency units using the same or similar fuel. Economic dispatch needs a well maintained balance among economic factors like reliability, efficiency, and some other factors including capacity of a given generating unit to change output at short notice, and scheduling limitations imposed by hydrological conditions, fuel properties and environmental laws. It means that the economic dispatch is known as cost depreciation process. The economic load dispatch problem includes a fuel cost function bounded with fuel cost equation and power balance constraints. This problem is expressed as follows:

a) Generator Fuel Cost Function: The factor of the rate which is considered in dispatching procedure section is the amount of the burning fuel in the fossil unit because nuclear thermal unit intent to be conducted at consistent output. The total cost of process combines the rates of labour, fuel rate, material and repairs. Generally, Fuel rates incomings includes the fix percentages of material, labour costs and repairs maintenance.

Simple power plants can be modeled as a transfer function of energy conversion from fossil fuel to electricity as described in Fig 1.1
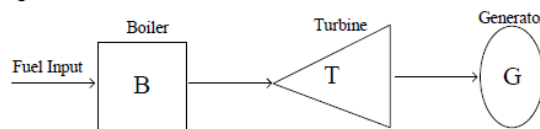

Fig. 1. Simple model of fossil plant

Minimize the generator fuel cost function,

$$F(P_g) = \sum_{i=1}^{n} F_i(P_{gi})$$

Where F_i is fuel cost of each generator and P_{gi} is the power generation output.

Fuel cost of operation of a generator is stated by a quadratic polynomial of power output P_{gi} as:

$$F_i(P_{gi}) = \sum_{i=1}^{n} (a_i P_{gi}^2 + bP_{gi} + c_i)\frac{\$}{hr}$$

Where, $F_i(P_{gi})$ is the fuel rate expressed in Rupees per hour ($/hr),

P_{gi} is the power generated (MW) ,

a_i, b_i, c_i are the fuel price coefficients of ith unit.

i^{th} Unit fuel price coefficients are a_i, b_i, c_i.

n is number of generating plants.

b) System Constraints: It has two types.
  i.   Equality Constraint

ii.   Inequality Constraint

Equality constraints
Power balance equation: The total generating power is equal to the transmission lines power loss P_L plus the total demand P_D . Hence, equality equation should be expressed as:
$\sum_{i=1}^{n} P_{gi} = P_D + P_L$ MW

Inequality constraints:
Generating unit capacity: Generated power output of individual generating unit is limited by minimum and maximum generation boundaries based on the output values and operational limits is needed to obtain the stable operation of electric power systems, as follows:
$P_{gi}^{min} \leq P_{gi} \leq P_{gi}^{max}$, for gi=1, 2… n

c) Problem Statement
Aggregating the inequality and equality constraints, and objective function, the problem is evaluated mathematically as a non linear emission and objective optimization problem as follows:
Minimize   : $[F_i (P_{gi})]$
Subject to   : $g_{gi}(P_{gi}) = 0$
$h_{gi} (P_{gi}) \leq 0$
Where, g_{gi} = equality constraint which describes power balance constraint.

h_{gi} = inequality constraint which describes generating unit capacity.

P_{gi} is the vector of state and control variables. The control variables include reactive power output and generator active, bus voltages while state variables includes load bus angles and voltage.

IV. PROPOSED METHOD
Tabu Search (TS)
Tabu search is a metaheuristic local search. The algorithm is fashioned by Fred W. Clove in 1986. The algorithm is based on the neighborhood definitions and actions converting a solution to its neighboring solutions. This technique begins with single solution approach and finds superior results by employing actions and by moving among neighbor solutions. By using rule set, the actions like availability, applicability and acceptance are handled.
The most significant fact of the tabu search algorithm is that when action is executed, it would not be accessible, until a certain amount of other actions performed. It is an iterative search approach. In tabu search 3 types of strategies are used: forbidding, freeing and short term. The forbidding strategy checks the entries of tabu search. The freeing strategy chooses the exits for the tabu list and also decides when the exit will happen. The short term strategy maintains the interaction between freeing and forbidding strategies to produce and choose the trial solutions. When a tabu move has a sufficiently attractive evaluation where it would result in a solution better than any visited so far, then its tabu classification may be overridden. Aspiration criterion is a condition that occurs when an override is allowed.
1.   Step 1: initialization: choose i i.e. initial solution from S. Set K=0 and i *= i
2.   Step 2: set K= K+1 and create a V* (subset) of N (i, K) solution in order to violate one tabu condition or to hold at least one aspiration condition.
3.   Step 3: choose the best solution j in V* and set the solution i=j.
4.   Step 4: check if f (i) < f (i*) and then set solution i* = i.
5.   Step 5: Update tabu list and aspiration criterion.
6.   Step 6: Stop: Stop the algorithm if stopping criteria is met otherwise go to step 2.

Tabu Search Stopping Conditions
Tabu search stopping conditions are given below:
a.   N (i, K+1) = 0. Which means there is no feasible solution is present in solution j neighborhood?
b.   K is larger than the maximum no. of allowed iterations.
c.   The no. of iterations since the last improvement of i* is larger than a specified number.
d.   Evidence can be given than an optimum solution has been obtained.

V. RESULTS AND DISCUSSION
In MATLAB R12, the IEEE 57 bus power system consisting 7 generator buses, 78 branches and 42 load buses is tested. The cost of fuel is expressed in $/hr as shown below:

$$F_1(P_{gi1}) = 0.0875 * P_{gi1}^2 + 25 * P_{gi1} + 0.0$$
$$F_2(P_{gi2}) = 0.0125 * P_{gi2}^2 + 50 * P_{gi2} + 0.0$$
$$F_3(P_{gi3}) = 0.2450 * P_{gi3}^2 + 25 * P_{gi3} + 0.0$$
$$F_6(P_{gi6}) = 0.0110 * P_{gi6}^2 + 50 * P_{gi6} + 0.0$$
$$F_8(P_{gi8}) = 0.0250 * P_{gi8}^2 + 25 * P_{gi8} + 0.0$$
$$F_9(P_{gi9}) = 0.0150 * P_{gi9}^2 + 50 * P_{gi9} + 0.0$$
$$F_{12}(P_{gi12}) = 0.0750 * P_{gi12}^2 + 25 * P_{gi12} + 0.0$$

And the constraints are:
$$0 \le P_{gi1} \le 570.65\ MW$$
$$0 \le P_{gi2} \le 120\ MW$$
$$0 \le P_{gi3} \le 160\ MW$$
$$0 \le P_{gi6} \le 100\ MW$$
$$0 \le P_{gi8} \le 535\ MW$$
$$0 \le P_{gi9} \le 120\ MW$$
$$0 \le P_{gi12} \le 425\ MW$$

TS Parameters values
The parameter values of tabu search include the length of tabu list, No. of neighborhood, diversification and generation as given below:
- Length of tabu list is considered as 10
- Neighborhood numbers are 45
- Diversification is 1
- Generation numbers are 200;

The minimum cost and active power generated are presented in Table1:

Table1:

Power in MW	Tabu search
P_{gi1} MW	132.68
P_{gi2} MW	87.05
P_{gi3} MW	45.31
P_{gi6} MW	84.456
P_{gi8} MW	492.274
P_{gi9} MW	84.05
P_{gi12} MW	330.56
Total Cost ($/hr)	40185
Time in sec	1.10

Time Comparison of Tabu search(TS) with Genetic algorithm (GA) and Hopfield neural network (HNN)

Table 2. Time Comparison of tabu search with genetic algorithm GA and HNN

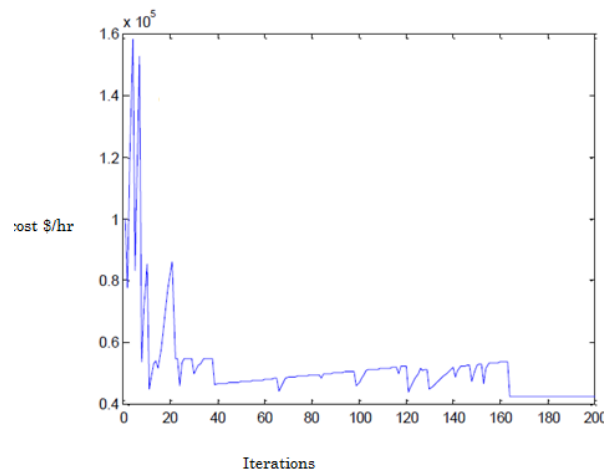| Case study	P_{gi1} (MW)	P_{gi2} (MW)	P_{gi3} (MW)	P_{gi6} (MW)	P_{gi8} (MW)	P_{gi9} (MW)	P_{gi12} (MW)	Cost ($/hr)	Time (sec)
TS	263.1252	98.4291	93.2111	39.6523	532.1753	92.2330	168.6534	42171	1.18
GA	142.1232	76.4856	62.8892	77.0123	505.5125	70.3009	350.6326	44230	1.76
HNN	210.4564	85.4456	75.9856	42.52363	510.6012	82.3195	360.6132	45160	1.82

Fig. 2 The cost generation during iterative process

VI. CONCLUSION

In this paper, we applied the method of optimization metaheuristics tabu search approach which is successfully implemented in order to minimize the cost of the generation plants in the power systems. It is noticed that ELD performance is enhanced as resulting rates of generating power unit's decreases with growth in electric power generating plants and by decreasing the transmission error loss in lines using computing methods. Tabu search is the best technique to resolve the combinatorial issues. The proposed technique improves the quality of the solution and takes less computational time.

REFERENCES

1. Environmental/economic power dispatch problem using multi-objective differential evolution algorithm_ L.H. Wua, Y.N. Wanga, X.F. Yuana, S.W. Zhoub 11 May 2010
2. Shahidehpour, S.M and Wang, C. "Effects of Ramp Rate Limits on Unit Commitment and Economic Load Dispatch" IEEE Transaction on Power Systems, Vol. 8, No. 3, August 1993, pp. 1341.M. Young, *The Techincal Writers Handbook.* Mill Valley, CA: University Science, 1989.
3. Evolutionary programming based economic dispatc units with non-smooth fuel cost functions Hong-Tzer Yang Member*, IEEE* Pai-Chum Yang Ching-Lien Huang *Member, IEEE* JEEE Transactions on Power Systems, Vol. 11,No. 1, February 1996
4. Chao -Hsien Chu, Chang-Chun-Tsai "A Heuristic Genetic Algorithm for Grouping Manufacturing Cells" 0-7803-3/01/$10.00 IEEE 2001, pp.310-317
5. A Genetic Algorithm for Solving the Optimal Power Flow Problem Tarek Bouktria a, Linda Slimania, Issue 4, January-June 2004 p. 44-58
6. D. E. Goldberg: AG exploration. Optimization et apprentissage automatique, Edition Addison Wesley France 1991
7. Glover,F. 1986, Future Paths for Integer Programming and Links to Artificial Intelligence. Computers and Operations Research. Vol 13, pp. 533-549.
8. P.H. Chen and H.C. Chang, "Large-scale economic dispatch approach by genetic algorithm," IEEE Trans. on Power Systems, vol. 10, no. 4, pp. 1919-1926, November 1995.
9. Hanafi, S. 2001. On the Convergence of Tabu Search. Journal of Heuristics. Vol. 7, pp. 47-58.
10. Palanichamy C. and Shrikrishna K. (1991), "Simple algorithm for economic power dispatch" electrical power syst. Res, Vol.21 pp 174-153.
11. B. Naama, H. Bouzeboudja, Y. Ramdani, A. Chaker « Hybrid Approach to the Economic Dispatch Problem Using a Genetic and a Quasi-Newton Algorithm». Acta journal, Electrotechnica et Informatica, Vol. 8, N°3, 2008, ISSN 1335-8243
12. Dhillon J.S., Parti S.C. and Kothari D.P., "Multiobjective Stochastic Optimal thermal power dispatch", ibid, pp. 136-140, 1987.
13. Happ H.H., "Optimal power dispatch- a comprehensive survey", IEEE Transactions on Power Apparatus and Systems, Vol.PAS-96,no.3, May/June1977.
14. J.A.Bland and G.P.Dawson,"Tabu Search and Design Optimization" *Computer - aided design*. Vol.23, No.3, pp.195-201, 1991.
15. Hamid Bouzeboudja, Abdelkader Chaker, Ahmed Alali, Bakhta Naama., "Economic Dispatch Solution Using A Real-Coded Genetic Algorithm," Acta Electrotechnica et Enformatica No. 4, Vol. 5, 2005
16. W. Ongsakul, and N. Ruangpayoongsak, Constrained dynamic economic dispatch by simulated annealing/genetic algorithms, in Proc. 22nd Power Ind. Comput. Applicat. (PICA)}, Sydney, Australia, 2001, pp. 207-212.
17. K, S Swarup, Non- memebre "Economic Dispatch Solution using Hopfield Neural Network" IE(I) Journal-EL , Vol 84,September 2004, pp. 77-82
18. W.N.W Abdullah, H. Saibon A.A.M Zain, K.L. Lo "Genetic Algorithm for Optimal Reactive Power Dispatch" IEEE Catalogue No: 1998X137 pp. 160-164
19. A novel crazy swarm optimized economic load dispatch for various types of cost functions Ranjit Roy a, S.P. Ghoshal b accepted 20 July 2007

20. J. S. Al-Sumait, J. K. Sykulski, and A. K. Al-Othman, "Solution of different types of economic load dispatch problems using a pattern search method," Electric Power Components and Systems, vol. 36, pp. 250-265, 2008.

21. Soliman Abdel – hady Soliman, Abdel – Aal Hassan Mantawy: Modern Optimization Techniques with Application in Electric Power Systems,Springer, pg185-230,2010

22. Aringhieri, R.: Solving chance-constrained programs combining tabu search and simulation. Lect. Notes Comput. Sci. 3059, 30–41 (2004)

23. de Backer, B., Furnon, V., Shaw, P., Kilby P., Prosser P.: Solving vehicle routing problems using constraint programming and metaheuristics. J. Heuristics 6, 501–523 (2000)

24. Battiti, R., Tecchiolli, G.: The reactive tabu search. ORSA J. Comput. 6, 126–140 (1994)

25. Battiti, R., Tecchiolli, G.: The continuous reactive tabu search: blending combinatorial opti- mization and stochastic search for global optimization. Ann. Oper. Res. 63, 151–188 (1996)Edmonds, J., and Jonhson, E.L., "Matching, Euler tours and the Chinese postman problem", *Mathematical Programming* 5/1(1973) 88-124.

26. Gendreau, M., Hertz, A., and Laporte, G., "Tabu search heuristics for the vehicle routing problem", Technical Report CRT-777, Centre de Recherche sur les Transports, Universit6 de Montr6al, 1993.

27. Gendreau, M., Laporte, G., and Potvin, J.-Y., "Metaheuristics for the vehicle routing problem", Technical Report CRT-963, Centre de Recherche surnles Transports, Universit6 de MontrEal, 1994.

28. Glover, F., "Tabu search - Part I," *ORSA Journal on Computing* 1 3 (1989) 190-206.

29. Glover, F., "Tabu search - Part II", *ORSA Journal on Computing* 2 1 (1990) 4-32.

30. Glover, F., "Multilevel tabu search and embedded search neighborhoods for the traveling salesman problem," Technical Report, Graduate School of Business and Administration, University of Colorado at Boulder, 1991.

31. Arene Thesen "Design and Evaluation of Tabu Search Algorithms for Multiprocessor Scheuling" *Journal of Hueristics*, 4:141-160, 1998

32. Glover, F., "Ejection chains, reference structures and alternating path methods for the traveling salesman problem", Technical Report, Graduate School of Business and Administration, University of Colorado at Boulder, 1992.

33. Lee, FN and Breipohi, AM. "Reserve Constrained Economic Dispatch with Prohibited Zones" IEEE Transactions on Power Systems, Vol. 8, No. 1, Feb. 1993, pp. 246.