Improved Tabu Search Algorithm to Economic Emission Dispatch with Transmission Line Constraint

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ABSTRACT

Every year the amount paid for one unit power consumption is increasing rapidly. By using Improved Tabu Search Algorithm (ITS) the cost per unit power consumption is reduced. The money spent by the consumer is reduced to a greater extent. Thus the economy of the country is improved. Economic load dispatch (ELD) is an important optimization task in power system. It is the process of allocating generation among the committed units such that the constraints imposed are satisfied and the energy requirements are minimized. There are three criteria in solving the economic load dispatch problem. They are minimizing the total generator operating cost, total emission cost and scheduling the generator units. In this paper the Improved Tabu Search (ITS) solution to economic dispatch problem is very useful when addressing heavily constrained optimization problem in terms of solution accuracy. In this paper the allocation of generation for each generator unit is optimized by Improved Tabu Search Algorithm. In thermal power plants the total cost of the power generation is depends upon fuel cost and emission cost. By the proposed method the total cost for power generation is enormously reduced. Results obtained from this technique clearly demonstrate that the algorithm is more efficient in terms of number of evolution to reach the global optimum point. The result also shows that the solution method is valid for real time applications and it provides challenges and opportunity to the Engineers to improve the economy of the country.

Keywords: Economic Dispatch, Emission Dispatch, Fuel Cost, Improved Tabu Search

1. INTRODUCTION

Energy management has to perform more complicated and timely system control function to operate a large power system reliably an efficiently. In electric power system operation, the objective is to achieve the most economical generation policy that could supply the local demands without violating constraints. Thermal stations, during power production, burn fossil fuels that generate toxic gases in their effluent and these become a source of pollution for the environment. Lack of planning while generating power puts the economical aspect in jeopardy. Within a plant, however, there are no transmission loss units; rather pollution exists due to emission. The cost minimum condition corresponds to minimum cost with considerable amount of emission. Similarly, the emission minimum condition produces minimum emission with higher deviation from minimum cost. These two conditions cannot be implemented simultaneously. Hence, the feasible optimum corresponds to a small deviation in cost with an allowable tolerance in emission taking into account emission constraints and this has been termed emission constrained economic dispatch (ECED).

Economic dispatch is one of the most important problems to be solved in the operation of power system. The traditional method such as lambda iteration method,

the base point, the participation factors method and gradient method are well known for the economic thermal dispatch of generators. All the methods as well known for the economic dispatch problem as a convex optimization problem and it assumes the whole of the unit operating limit (P_{min}) and the maximum generation limit (P_{max}) is available for operation.

This paper work deals with the economic scheduling problem namely the economic thermal power dispatch. In seeking the solution for the economic dispatch problem (EDP) the main aim is to operate a power system in such a way to supply all the loads at the minimum cost. The solution technique which is applied to the economic load dispatch is Improved Tabu search (ITS) method. The basic idea of the ITS approach is to use adaptive memory structures and associated strategies to explore the search space of feasible solutions by means of a sequence of moves. The simplest version of this method only makes use of its short term memory process. The elements of the more from the current solution, to its selected neighbor are partially or completely recorded in the Tabu List to forbid reversal of the replacement in future iterations. Without his assurance, the search would cycle between the first encountered local optimum and its neighbor. Considerable success is achieved for short term

memory, which makes use of frequency information and more advanced principles. This influences the effective implementation of Improved Tabu Search.

A good deal of literature is available pertaining to the topic of research considered in this thesis. The traditional method of solving economic dispatch problems such as lambda-iteration and gradient method requires the unit input-output curves of generators. However, these curves do not increase monotonically due to prohibited operating zones. Hence, the traditional dispatch algorithms cannot be directly used to optimize such non-linear cost function. Wong suggested the Evolutionary programming based algorithm for environmentally constrained economic dispatch [1] to solve the highly non linear economic dispatch problem without restrictions on the shape of the fuel cost functions. These applications involved a large number of iterations and susceptible to the related control parameters. Park analyzed the adaptive learning approach in the Hopfield Neural Network [2] using the slope adjustment and has adjustment methods for application to economic load dispatch. These methods reduce transient period drastically. The adaptive learning in both methods gives better response compared to fixed learning rate. The bias adjustment method gives good response especially in the beginning of the process. Both methods reduced the number of iterations to one half of the traditional Hopfield neural network. When the momentum is introduced to all methods in either input or gain, the number of iterations and the computation time are reduced in the order of magnitude. Sewothul and Rughooputh have studied genetic algorithm for economic dispatch with valve point effect [3] develops four genetic algorithms: simple genetic algorithm, Simple genetic algorithm with generation-apart elitism, Simple genetic algorithm with atavism and atavistic genetic algorithm for non monotonically increasing cost functions.

Basu analyzed the interactive fuzzy satisfying-based simulated annealing technique [4] for economic emission load dispatch with non smooth fuel cost and emission level functions treats economic and emission as competing objectives for optimal dispatch, which requires some form of conflict resolution to arrive at a solution. Assuming that the decision maker has imprecise or fuzzy goals for each of the objective functions, the multiobjective problem is transformed into a minimax problem, which is then handled by the simulated annealing technique. Khamsawang and Pothiya have suggested a novel method on simple Tabu search algorithm (TSA) to solve economic dispatch (ED) problem for thermal power plants, which we call Distributed Tabu Search algorithm (DTSA) [5]. It consists of thirteen generating units with valve point effect fuel functions. Basu analyzed the dynamic economic emission

dispatch [6] is an extension of the conventional economic emission dispatch problem that takes into consideration the limits on the ramp rate of the generating units. The multiobjective problem is converted into a single-objective optimization by goal-attainment method which is then handled by particle swarm optimization method. Muralidharan and Srikrishna have studied dynamic programming recursive approach for the Emission constrained economic dispatch [7] presented a multiobjective and multi stage decision making problem has been solved analytically without the familiar lambda iteration method.

The optimization algorithm has been developed with a sequential dynamic programming model. The salient feature of this technique is that all the former conventional procedures have been avoided completely. Whei-Min Lin and Fu-Sheng Cheng implemented an Improved Tabu Search Algorithm [8] for economic dispatch with non continuous and non smooth cost functions. Modified Tabu Search generates new population from one candidate and usually converges to local optimum very quickly, for ITS vectors with fitness score good enough would be used as candidates to create new solutions regardless of Tabu restrictions. The theory of tabu Search has been well developed an Improved Tabu Search Algorithm (ITS) to make tabu Search more practicable in real valued systems.

2. PROBLEM FORMULATION

The objective of solving the economic dispatch problem in electric power system is to determine the generation levels for all on-line units which minimize the total fuel cost and minimizing the emission level of the system, while satisfying a set of constraints. It can be formulated as follows:

The economic dispatch problem can be modeled by

$$\text{Minimize } F_T = \sum_{i \varepsilon \Omega} F_i(P_i) \ \text{ Rs/hr} \tag{1}$$

Where

FT is the total fuel cost

$F_i(P_i)$ is the fuel cost of generating unit i

A. Fuel Cost Function

The fuel cost function of a generating unit is usually described by a quadratic function of power output P_i as:

$$F_i(P_i) = a_i P_i^2 + b_i P_i + c_i \ \text{Rs/hr} \tag{2}$$

Where

a_i, b_i and c_i are the cost co-efficient of unit i.

B. Emission Equation

The Emission equation of a generating unit is usually described by a quadratic function of power output P_i as:

$$F_i(P_i) = d_i P_i^2 + e_i P_i + f_{i \text{ Kg/hr}} \qquad (3)$$

Where

d_i, e_i and f_i are the emission co-efficient of unit i.

C. Emission Constrained Cost Equation

The Emission constrained cost equation can now be formulated as:

$$F_i(P_i) = (a_i P_i^2 + b_i P_i + c_i) +$$
$$+ h_i (d_i P_i^2 + e_i P_i + f_i) \text{ Rs/hr} \qquad (4)$$

Where

$$h_i = F_i \text{max} / E_i \text{max} \qquad (5)$$

$$F_i \text{max} = a_i P_i^2 \text{max} + b_i P_i \text{max} + c_i \text{Rs/hr} \qquad (6)$$

$$E_i \text{max} = d_i P_i^2 \text{max} + e_i P_i \text{max} + f_{i \text{Kg/hr}} \qquad (7)$$

D. Transmission Loss

The transmission losses P_t can be found using B_{mn} coefficients

$$P_L = \sum_{i=1}^{n} \sum_{i=1}^{n} B_{ij} P_j P_i \qquad (8)$$

Where

B_{ij} is the transmission line coefficients

E. Power Balance Constraints

Power Balance Constraints: The total generation must supply the demand

$$\square (P_i) = P_D \qquad (9)$$

Where

P_D is the load demand

F. Generator Limit Constraints

The power generation of unit 'n' should be between its minimum and maximum limits.

$$P_n \text{min} < P_n < P_n \text{max} \qquad (10)$$

Where

P_i min is the minimum generation limit of unit i

P_i max is the maximum generation limit of unit i

3. IMPROVED TABU SEARCH ALGORITHM

An Improved Tabu Search (ITS) search is a higher-level method or strategy for solving optimization problems. The ITS approach can be imposed on any procedure whose operations produce a sequence of moves that lead from one trail solution to another. Each move is obtained from a set of available alternatives that are be evaluated by one or more functions that measure their attractiveness in some local sense. Applying to the optimization problems, the ITS starts at some initial solution and then moves to a neighboring solution. A neighboring solution is generated by a set of admissible moves. At each iteration the method moves to the best solution in the neighborhood of the current solution. The best solution of all stages is sorted as the new best solution and used as forward initial solution for every stage. Finally, the searching of all stages has completed their solutions, applying the global updating to select the best solution. The details of the ITS is applied to ED problem are given in the following Algorithm:

- Set initial solution of stage i to be current solution.

- $S^i O = (P_1\ P_2 \ldots\ldots P_N)$ where $P_1\ P_2 \ldots\ldots P_N$ = Output power of Generating unit.

  » N = Number of total generating unit in this system.

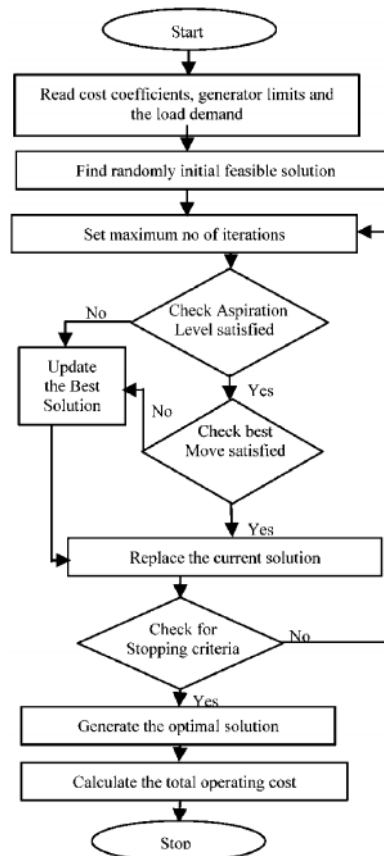- Set, Iteration count $K = 0$.

- Tabu list as empty.

Fig. 1: Flow Chart for Improved Tabu Search Application to Economic Load Dispatch

- Calculate the total fuel cost function of each stage $F_T(S^i_O)$.

- Set best solution (S^i_b) = current solution S^i_O and $F_T(S^i_O) = F_T(S^i_b)$.

- Find as set of neighbors solution $S^i_{neighbour}$ of (S^i_b).

- Calculate total fuel cost function F_T (S^ineighbour).

- If F_T (S^ineighbour) < F_T (S^i_b), update solution.

- Set (S^i_b) = (S^ineighbour), else do not update solution.

- Update tabu list, i,e, regency frequency & move direction are update.

- Check the condition of interchange solutions. If reaches the appropriate point, inter change solutions between stages; the best solution of all stages is sorted as the new best solution and used as forward initial solution for every stage. Set iteration counter $K = K+1$ and go to Step 5.

- Stop if the termination criterion is satisfied and global updating solution else go to step 5.

4. EXPIREMENTS AND RESULTS

The power system economic dispatch problem based on the concept of Improved Tabu Search method has been tested on 3-generator system. Multiple generator limits and total operating cost of the system is simulated in order to evaluate the correctness as well as accuracy of this method. The test system consists of 3-generating units with various demand of 300-700 MW. The cost coefficient, emission coefficient and generating limits of the 3-generator system are shown in table (I).

The Loss Coefficient Matrix of 3- Generator System

$$B_{mn} = \begin{vmatrix} 0.000071 & 0.000030 & 0.000025 \\ 0.000030 & 0.000069 & 0.000032 \\ 0.000025 & 0.000032 & 0.000080 \end{vmatrix}$$

Table I
Cost Coefficients, Emission Coefficients and Power Limits for Three Generator System

Generator	a_i	b_i	c_i	d_i	e_i	f_i	P_{min}	P_{max}
1	0.03546	38.30553	1243.5311	0.00683	-0.54 551	40.26690	20	200
2	0.02111	36.32782	1658.5696	0.00461	-0.51160	42.89553	15	150
3	0.01799	38.27041	1356.6592	0.00461	-0.51160	42.89553	18	180

5. SIMULATION TEST RESULTS

The Improved Tabu Search Algorithm is used to solve the Economic Dispatch problem for 3-generator test system. The simulation is carried out using Mat Lab 7.0 software. The total operating cost, emission level and transmission loss of the system are minimized. The computational results of table (II) consists of three generator test system, shows that ITS fuel cost function, emission level & Transmission loss are less than conventional methods. The test system data produce the better result for 3-generating units. It concludes that the total fuel cost and emission level is minimum in Improved Tabu Search Algorithm compared to other techniques with considering fuel cost functions, emission equations, emission constrained cost equation, transmission line constraints, power balance constraints and generator limit constraints. In comparison of the test system, it can be seen that when a large scale problem, ITS can clearly obtain solution better than other methods and converges to near global minimum with less search account.

Table II
Fuel Cost, Emission and Transmission Loss Values for 3-Generator System Under Various Load Conditions

Sl.no	Power demand (mw)	P_1(MW)	P_2(MW)	P_3(MW)	P_{loss}(MW)	Fuel Cost (Rs/hr)	Emission Release(kg/hr)
1	300	76.5863	115.2465	112.2969	4.1296	16392	127.2929
2	350	89.5245	134.4453	131.6782	5.6480	18589	159.0743
3	400	104.0372	150.0000	153.3721	7.4093	20845	200.1917
4	450	129.3902	150.0000	180.0000	9.3902	23204	254.0819
5	500	181.4774	150.0000	180.0000	11.4774	25774	336.2607
6	550	211.3118	161.3118	191.3118	13.9354	28326	424.0469
7	600	228.8856	178.8856	208.8856	16.6568	30837	509.2984
8	650	246.5455	196.5455	226.5455	19.6366	33407	604.9546
9	700	264.2929	214.2929	244.2929	22.8788	36037	711.1699
10	750	282.1291	232.1291	262.1291	26.3872	38727	828.1029

6. SUMMARY AND CONCLUSION

Implementing Improved Tabu Search Algorithm method in all power generating stations is a challenge to the Engineers and it gives an opportunity to reduce the cost per unit power generation. This will leads to economy growth of the country. The quality of the solution shows that an Improved Tabu Search offers a promising viable approach for solves the economic emission dispatch with transmission line constraints. The solution is analytic in nature with high accuracy involving less computational time. It is used for any online applications becomes boundless. The numerical results have shown the performance and applicability of the proposed method. This proposed algorithm is very well defined and the solution accuracy is excellent is conformity with the conventional techniques. The results show that Improved Tabu search Algorithm (ITSA) can converges to near global minimum with less search account. It is high efficiency than other methods. Thus, it obtains the solution with high accuracy.

7. ACKNOWLEDGEMENT

REFERENCES

[1] K. P. Wong and J. Yuryevich, "Evolutionary-Programming-based Algorithm for Environmentally-constrained Economic Dispatch," *IEEE Trans. Power System.*, **13**, pp. 301–306, May 1998.

[2] J. H. Park, K. Y. Lee and A. S. Yome, "Adaptive Hopfield Networks for Economic Load Dispatch," *IEEE Trans. Power System.*, **13**, pp. 519–526, May 1998.

[3] Liladhur G. Sewothul, Robert T.F. Ah King and Harry C.S.Rughooputh, "Genetic Algorithms for Economic Dispatch with Valve Point Effect", *Proceedings of the IEEE, International Conference on Networking, Sensing & Control*, pp.1358-1362, March 2004.

[4] M. Basu, "An Interactive Fuzzy Satisfying-based Simulated Annealing Techniques for Economic Emission Load Dispatch with Nonsmooth Fuel Cost and Emission Level Functions", *Electric Power Components and Systems*, **32**, No.2, pp.163-173, 2004.

[5] S.Khamsawang, S.Pothiya and C.Booseng, "Distributed Tabu Search for Solving the Economic Dispatch Problem", *IEEE Trans. Power System.*, **20**, pp. 484–487, 2004.

[6] M. Basu, "Particle Swarm Optimization Based Goal-attainment Method for Dynamic Economic Emission Dispatch", *Electric Power Components and Systems*, **34**, pp.1015-1025, 2006.

[7] S.Muralidharan, K.Srikrishna and S. Subramanian, "Emission Constrained Economic Dispatch- A New Recursive Approach", *Electric Power Components and Systems*, **34**, No.3, pp.343-353, 2006.

[8] Whei-Min Lin, Fu-Sheng Cheng and Min-Tong Tsay, "An Improved Tabu Search for Economic Dispatch with Multiple Minima", *IEEE Trans. Power System*, **17**, No.1, pp. 108-112, Feb 2002.