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Solution to Economic Power Dispatch Planning Problem considering Generator Constraints using Artificial Bee Colony Algorithm

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Abstract

Optimum active and reactive power dispatch is an inherent part of power system generation planning and it is the need of an hour for the electrical utilities and power engineers to dig this area in short and long term planning scenarios. Load demand requirements subjected to economic feasible solutions matching voltage profile, power demand, minimization of losses, voltage stability and improve the capacity of the system is the need of the hour. Optimization techniques based on evolutionary computing, artificial intelligence, search method finds their applications in the area of economic load dispatch planning to reach global optimal solution for this multi-decision, multi-objective combinatorial problem subjected to different constraints. In this paper, ant bee colony based algorithm has been proposed to solve economic dispatch problem. Unlike other heuristic algorithms, ABC utilizes search space as multi-step decision process. It possesses a flexible and well-balanced operator to enhance and adapt the global and fine tune local search to follow the minimum cost path in the search boundary. The suggested technique is tested on IEEE 25 bus system. Test results are compared with other techniques presented in literature.

***Keywords**: Ant Bee Colony (ABC), Economic Dispatch (ED)*

1. Introduction

The economic dispatch (ED) problem is one of the most important areas of today's power system. The purpose of the ED is to find the optimum generation among the existing units, such that the total generation cost is minimized while simultaneously satisfying the power balance equations and various other constraints in the system. Below are the suggested techniques in the literature -

Amudha A. *et al* [1] solved unit commitment problem using worst fit algorithm considering the effect of reserve on profit basis .Bavafa M. *et al* [2] implemented a hybrid approach based on lagrange algorithm with evolutionary and quadratic programming for short thermal unit commitment considering ramp rate constraint. Catalao J.S. *et al* [3] proposed a profit based unit commitment with constraints of emission limitation. A trade off has been done between profit and emission in order to assist decision makers. Chang G.W. *et al* [4] proposed a mixed integer linear programming method for unit commitment optimization. This approach is suitable for both traditional and deregulated environment. Christober C. *et al* [5] coined an algorithm based on genetic algorithm to minimize the total operating cost. It uses standard reproduction, cross over and mutation operators for the optimization. Christober C. *et al* [6] proposed a neural network based tabu search for

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unit commitment optimization which is more efficient than conventional tabu search. Christober C. *et al* [7] presented approach based on evolutionary programming simulated annealing method considering cooling and banking constraints for cost minimization. Fei L. and Jinghua L. [8] designed algorithm based on local search which combines interior search method for large power system. Ganguly D. *et al* [9] proposed a new genetic approach based on parallel system to handle impossible solution in an organized fashion for thermal unit commitment. Barquin J. [10] proposed an algorithm for self unit commitment for day ahead market based on simple bids. Iguchi M. and Yamashiro S. [11] implemented an efficient scheduling method for hydro-thermal units considering the account of transmission network. It consists of different stages and constraints are relaxed at every stage and transmission losses are calculated at every stage. Im T.S and Ongsakul W. [12] implemented an Ant colony search algorithm based on new co-operative agent approach for economic dispatch and unit commitment. Jenkins L. [13] implemented four hybrid algorithms based on simulated annealing, local search, tabu search, dynamic programming and genetic algorithms and compared the cost with earlier literature .Klir J. *et al* [14] presented different fuzzy techniques for optimization. Gonzalez J.G and Kuan E. *et al* [15] implemented an algorithm for unit commitment optimization considering the complete network modeling and bender method is employed to decompose the problem into integer and continuous variables. Larsen T.J. *et al* [16] developed a model based on sequential time step. It decomposes the problem at every time step and is solved by free marked model. Liang R.H. and Kang F.C. [17] proposed an extended mean field annealing neural network approach to solve short term unit commitment problem which is tested on Taiwan power system. Liao G.C. and Tsao T.P. [18] introduced hybrid algorithm based on fuzzy logic, tabu search and genetic algorithm to solve short term unit commitment results in reduction in computation time. LiaoG.C. and Tsao T.P. [19] implemented an algorithm based on genetic algorithm and Meta Heuristic method for unit commitment problem. It includes genetic algorithm, fuzzy logic and simulated annealing to determine shutdown and startup schedule. Maojun L. and Tiaosheng T. [20] proposed a modified genetic algorithm with three genetic operators called Gene Complementary Genetic Algorithm. Momoh J.A. and Zhang Y. [21] proposed a unit commitment method based on adaptive dynamic programming algorithm. Nagrath and Kothari [22] presented different aspects of power system analysis. Norhamim *et al* [23] presented an approach for cost minimization based on unit commitment and economic dispatch in large scale power system and comparison has been done with lagrange algorithm. Senjyu Pappala V.S. and Erlich I. [24] proposed a new approach based on adaptive particle swarm optimization. It results in reduction in no. of decision variables. . Park J.D. *et al* [25] proposed an algorithm based on the effect of economic dispatch and consideration of ramp constraints. It reduces the generation level of less efficient units by commiting additional units or by economic dispatch. J.D. *et al* [26] did the stochastic analysis based on uneven load demand on hour basis with the consideration of hit rate of units. Raglend I.J. *et al* [27] proposed an algorithm including operational, power flow and environmental constraints to plan secure and economic generation schedule. Rampriya B. *et al* [28] proposed a method in deregulated power system based on lagrangian firefly algorithm for profit based unit commitment. Saber A.Y. *et al* [29] introduced algorithm based on fuzzy adaptive particle swarm optimization approach. It tracks continuously changing solutions. Sadati N. *et al* [30] proposed a technique based on particle swarm fusion with simulated annealing for unit commitment optimization. It performs two functions unit schedule and economic dispatch. Seifi H. [31] presented different issues in power system planning. Senjyu T. *et al* [32] implemented an algorithm based on genetic algorithm for large scale unit commitment with the consideration of new genetic operator and unit integration technique. Senjyu T. *et al* [33] presented a genetic algorithm based on unit.Characteristics classification. Numerical results for system of up to 100 units are compared to previously reported results. Simopoulos D.N *et al* [34] implemented an enhanced simulated annealing algorithm for unit commitment problem combined with dynamic economic dispatch. Sriyanyong P. and Song Y.H.[35] proposed a hybrid algorithm based on Particle Swarm Optimization and Lagrange and performed on various 4 and 10 unit systems. Vasan H.P [36] presented hopefield neural network approach for unit commitment and economic dispatch problem. Wang B. *et al* [37] implemented algorithm for rescheduling of units in fuzzy logic. They proposed a heuristic algorithm called local convergence averse binary particle swarm optimization to solve the unit commitment problem. Wang M. *et al* [38] proposed a technique considering various constraints for the optimization of unit commitment. It uses the combination of dynamic programming with economic dispatch and comparison with lagrange algorithm has been done. Woods and Woolenberg [39] shared different scenarios of operation and control of power system. Zheng H. and Gou B. [40] designed new algorithm based on ON-OFF unit schedule by using lagrange algorithm which is superior than dynamic programming. Zhu [41] presented different optimization methods of power system. Navpreet Singh Tung *et al*[42,43] introduced various unit commitment aspects. Hamid Boujeboudja [44] proposed real coded genetic algorithm for unit commitment problem.

2. Problem Formulation

All The ED problem can be expressed as.

- . Fuel Cost Model

$$\text{Min} \quad \sum_{i=1}^{NG} F_i(P_{Gi})$$

$$F_i(P_{Gi}) = \left(a_i + b_i P_{Gi} + c_i P_{Gi}^2\right) \quad \text{where i=1.....N} \qquad (1)$$

- Constraints

$$P_{Gi}^{\min} \le P_{Gi} \le P_{Gi}^{\max} \quad \text{for i= 1,...,NG}$$

$$\sum_{i=1}^{NG} P_{Gi} - D - P_L = 0$$

Where

$$P_L = \sum_{i=1}^{N}\sum_{j=1}^{N} P_{Gi} B_{ij} P_{Gj} + \sum_{i=1}^{N} B_{0i} P_{Gi} + B_{00} \qquad (2)$$

3. Ant Bee Colony

The Algorithms based on ants were first proposed by Marco Dorigo and his colleagues in the year 1991 as a multi-agent approach to difficult combinatorial optimization problems Inherent features such as positive feedback, distributed computation approaches are some of the important characteristics of ant algorithms. Currently, a lot of happenings in the research community to extend/apply ant-based algorithms to various optimization problems. Social insects like ants, bees work by themselves in their routine tasks, independently of other members of the colony. However, when they work as a group, they are able to solve complex problems emerging in their daily lives, by means of mutual cooperation. This evolving behavior of self-organization by a group of social insects is known as “swarm intelligence” which is mainly due to the four basic ingredients-

a) Positive feedback
b) Negative feedback
c) Amplification of fluctuations
d) Multiple interactions.

An interesting behavior of ant colonies is their foraging behavior, how ants can find shortest paths between food sources and their nest. While walking from food sources to the nest and vice versa, ants deposit on the ground a chemical substance called pheromone, forming in this way a pheromone trail. Ants can smell pheromone and, when choosing their path, they tend to choose, in probability, paths marked by strong pheromone concentrations. The pheromone trail allows the ants to find their way back to the food by their nest mates. The emergence of this shortest path selection behavior can be explained in terms of autocatalysis (positive feedback) and differential path length which uses a simple form of indirect communication mediated by pheromone laying, known as "stigmergy" through the environment, either by physically changing, or by depositing something on the environment.

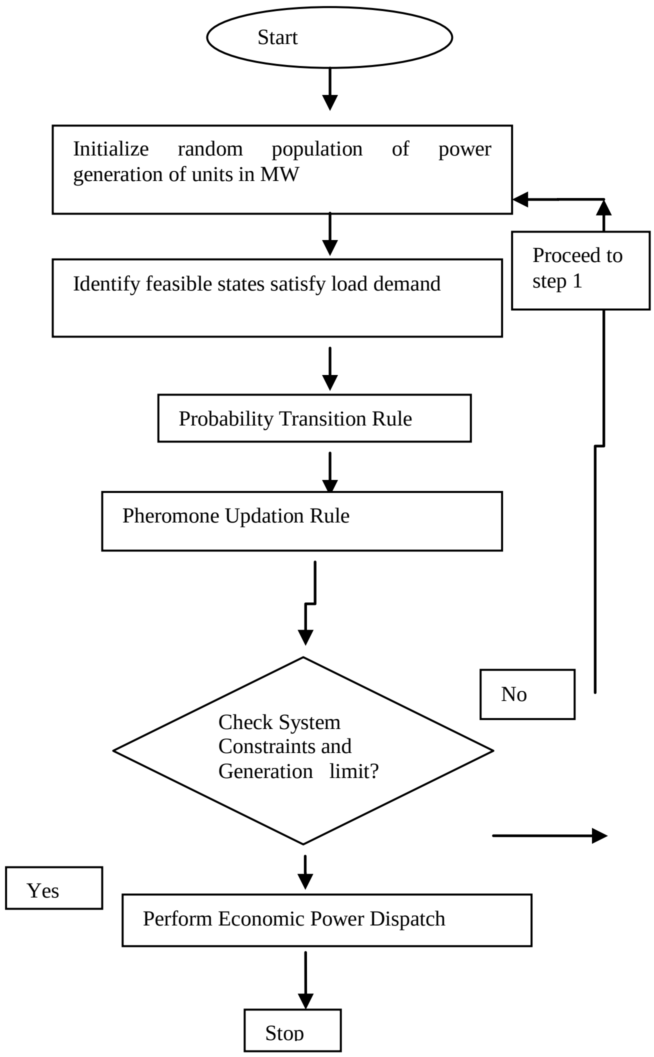
a) Ants arrive at a decision point.

b) Some ants select the upper path and some the lower path. The decision is random.

c) Since ants flow at static speed, the ants which choose the lower, shorter, path reach the opposite decision point faster than those which choose the upper, longer, path.

d) Pheromone assembles at a higher rate on the shorter path.

- ***Flow Chart***



4. Economic Power Dispatch using Ant Bee Colony

A. Variables

Power Generation (PG) and cost coefficients (a,b,c) of units with objective function as fuel cost, quadratic in nature. Power Generation variable should be initialized as starting point for initial solution in ant bee colony algorithm.

B. Constraints

Equality Constraints: (P_G-P_D-P_L=0)

In-Equality Constraints: Power Generation should be between minimum and maximum limit of power generation.

Variables in constraints should be incorporated in pattern search algorithm.

C. Stopping Criteria

It is the maximum generation limit for optimum solution.

5. Simulation Results

This proposed approach is tested on IEEE 25 bus system [44]. Simulation results are achieved and compared with other techniques presented in literature.

Table 1. Power Generation, Total Cost and Computational Time using Ant Bee Colony with Load Demand 730 MW

PG1 (MW)	PG2 (MW)	PG3 (MW)	PG4 (MW)	PG5 (MW)	Cost ($/hr)	Time (Sec)
188.5809	128.7602	147.5939	29.2933	256.1478	1960.3	1.2

In Table 1, power generation is presented for each generator and total operating cost is presented. Total CPU computation time is calculated for ED problem

Table 2.Results Comparison with Other Techniques [44]

Parameters	ABC	RCGAs	BCGAs	QN
PG1 (MW)	188.5809	213.68	206.72	211.30
PG2 (MW)	128.7602	127.46	121.64	126.30
PG3 (MW)	147.5939	141.93	151.82	151.29
PG4 (MW)	29.2933	29.53	33.21	71.24
PG5 (MW)	256.1478	258.86	258.05	211.31
Cost ($/hr)	1960.3	2010.8	2011.0	2029.3
Time (Sec)	1.2	1.6	4.78	0.0

In Table 2, comparison has been shown for power generation .total cost and CPU time among proposed technique artificial bee colony, real coded genetic algorithm, binary coded genetic algorithm, Quasi newton .

Table 3. System Data

Unit	a($/MW2)	b($/MW)	c($)	PG_{min}(MW)	PG_{max}(MW)
1	0.0015	1.8	40	100	300
2	0.0030	1.7	60	80	150
3	0.0012	2.1	100	80	200
4	0.0080	2.0	25	20	100
5	0.0010	1.9	120	100	300

6. Conclusion

An application of soft computing techniques in economic load dispatch planning optimization has been inherently evolving for last few decades. Different evolutionary and intelligent computation methods whether stand alone or hybrid in nature have been developed and successfully applied to economic load dispatch area. In the current research, an application of ABC algorithm has been applied successfully for economic active power dispatch problem. Proposed technique is tested on IEEE 25 bus system. Test results reveal the minimum operating cost, optimum power generation and high speed convergence of solution. A comparison has been made with other techniques presented in literature. It out-performs other techniques presented in literature in terms of computation speed, fuel cost and power generation. Hence, ABC algorithm is more robust and lead to optimal solution in economic active power dispatch problem.

7. Future Scope

Upcoming research involves the expansion of ABC lead to the formulation and development of hybrid algorithm to polish the best solution search capacity of the proposed technique as well as fast convergence for optimal solution with incorporation of practical constraints.

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NOMENCLATURE

N	Number of units
P_D	Power Demand
P_{Gmax}	Maximum limit of Unit
P_{Gmin}	Minimum Limit of Unit
P_G	Power Generation
C	Total Cost
P_L	Power Losses
a,b,c	Cost Coefficients
B	Loss Coefficients

