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Solution of Economic Power Dispatch using Teaching Learning Algorithm

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Abstract:
In this paper, a Teaching Learning Algorithm (TLA) method is proposed to solve the non-convex economic power dispatch (NCEPD) problem in power systems, whose objective is to simultaneously minimize the generation cost rate while satisfying equality and inequality constraints. The feasibility of the TLA-NCEPD method is demonstrated on thirteen unit power systems. It is compared with the pattern search, improved genetic algorithm, cultural differential evolution and quantum particle swarm optimization in terms of solution quality. The simulation results show that the proposed TLA method is able to obtain higher quality solutions stably and efficiently in the NCEPD problem than any other tested optimization algorithm.

Keywords: Economic power dispatch, Non-convex, Quadratic cost functions, Teaching learning Algorithm, Valve point effects

1. Introduction

Economic Power dispatch (EPD) problem is one of the major mathematical optimization issues in power system operation that attracts researchers' attention all the way. Economic dispatch seeks ''the best" generation schedule for the generating plants to supply the required demand plus transmission losses with the minimum production cost. Various investigations on EPD have been undertaken till date, as better solutions would result in significant economical benefits. To improve the solution quality, a lot of researches have been done and various methods have evolved so far in the field of economic power dispatch. Previously a number of conventional approaches such as gradient method, linear programming algorithm, lambda iteration method, quadratic programming, nonlinear programming algorithm, Lagrange relaxation algorithms have been applied for solving the EPD problems.

All classical calculus-based methods fail in solving these types of problems. Therefore, with the availability of high-speed computer system, more and more interests have been focused on the application of artificial intelligence technology for solution of EPD problems. Several artificial intelligence methods such as Improved genetic algorithm [1], Cultural differential evolution [2], GA-PS-quadratic programming [3], Quantum particle swarm optimization [4], Pattern search method [5] have been developed and applied successfully to EPD problems. In this paper, a recent heuristic algorithm introduced by Rao et al. [7] named teaching learning algorithm (TLA) [8], based on the effect of the influence of a teacher on the output of learners in a class, is utilized for the solution of NCEPD problem.

2. NCEPD formulation

The objective of the classical NCEPD problem is to minimize the total system fuel cost over some appropriate period while satisfying various constraints, and thus the problem can be defined as the following constrained optimization problem:

$$\sum_{i=1}^{N} F_i(P_i) = a_i + b_i P_i + c_i p_i^2 + \left| e_i \sin(f_i (P_{i,\min} - P_i)) \right| \quad (\$/h) \qquad (1)$$

Where a_i, b_i, c_i are the fuel cost coefficients and e_i, f_i are the valve point coefficients.
N is the number of generating units.

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Power balance constraints: The generated power of all thermal generating units must gratify the load demand (2), which is defined as

$$\sum_{i=1}^{N} P_i = P_d \ (MW) \tag{2}$$

Power generation limits: The generating unit power output must falls within its minimum ($P_{i,\,min}$) and maximum limits ($P_{i,\,max}$), which can be formulated as:

$$P_{i,\min} \le P_i \le P_{i,\max} \tag{3}$$

3. Teaching Learning Algorithm

The TLA is a population based algorithm motivated by the influence of a teacher on learners. It is based on the cause of influence of a teacher on the output of learners in a class. Also it requires only the tuning of common control parameters and not the algorithm-specific parameters, which makes it superior than other optimization algorithms. In order to find the solution for NCEPD, a TLA technique is proposed to solve the non-linear objective function. TLA is like other evolutionary algorithms, each searching generation includes initializing of class, Teaching phase, Learning phase and Termination.

The steps of the TLA for the proposed NCEPD problem are summarized as follows.

Initialization of NCPED Problem

Step 1: Define the NCEPD optimization problem as minimization problem.

Step 2: Population size (*Ps*), number of design variables (*Nd*) which represents number of generating units, maximum and minimum generation limits (limits of design variables) and stopping criteria (maximum number of iterations) are defined in this step.

Teaching Phase

Step 3: Evaluate the difference between existing mean result and best mean result by utilizing T_f.

Learning Phase

Step 4: Update the learner's generation value with the help of teacher generation.

Step 5: Update the learner's generating value by utilizing the generating value of some other learner.

Termination Criteria

Step 6: Repeat the procedure from step 2 to 5 till the maximum number of iterations is met.

4. Results and Discussions

To assess the efficiency of the proposed TLA approach, NCEPD is carried out on 13 unit system. The software has been written in MATLAB-7.3 language and executed on Intel core i3 processor with 4GB RAM. The performances of the tested algorithm were investigated in terms of solution quality obtained from 100 iterations. In addition, convergence properties of the algorithms were analysed through visualizing the dynamic changes of the objective function value on the course of running.

This system consists of 13 thermal generating units. The load demand is 1800 MW. The characteristics of the 13 thermal units are available in [6]. TLA based NCEPD is carried out and the results are listed in Table 1. The best solution of the NCPED problem achieved by TLA for a demand of 1800 MW is 17963.82 $/h. The detailed scheduling of 13 thermal generating units are listed in Table 1

Table 1: NCEPD results of 13-unit system with valve point effects using TLA.

P_d (MW)	**1800**
P_1	628.3185
P_2	149.5996
P_3	222.7490
P_4	109.8665
P_5	109.8665
P_6	109.8665
P_7	109.8664
P_8	60

P_9	109.8665
P_{10}	40
P_{11}	40
P_{12}	55
P_{13}	55
Fuel cost ($/h)	**17963.82**

The solution obtained by TLA algorithm and the best solutions achieved by Pattern search method [5], GA-PS-quadratic programming [3], Improved genetic algorithm [1], Cultural differential evolution [2], Quantum particle swarm optimization [4] are listed in Table 2. From the results seen in Table 2, it is seen than that TLA method can obtain lower generation cost than the other mentioned methods.

Table 2: Comparison of NCEPD with previous publications for P_d=1800 MW.

Optimization method	Fuel cost ($/h)
Pattern search method [5]	17969.17
GA-PS-quadratic programming [3]	17964.25
Improved genetic algorithm [1]	17963.98
Cultural differential evolution [2]	17963.94
Quantum particle swarm optimization [4]	17969.01
TLA	**17963.82**

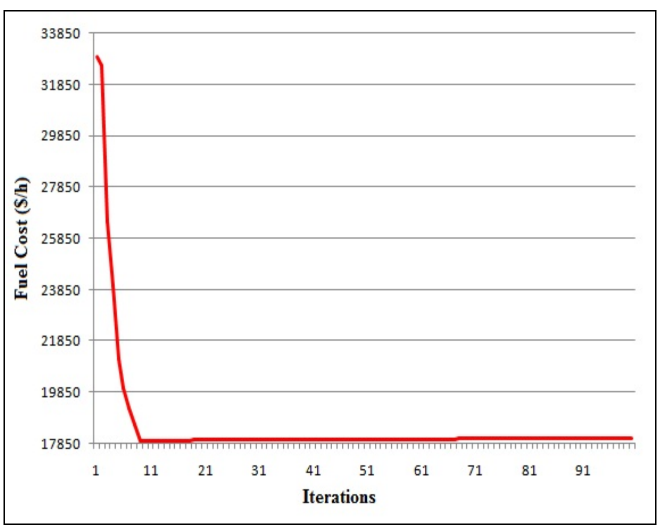

Fig. 1: Convergence characteristics of 13 unit system by TLA for Pd=1800 MW

The convergence test is carried out on 13 unit system. A convergence characteristic of the 13-generator systems by TLA algorithm is shown in Fig. 1. The aim of this investigation is to make a further comparative analysis of the performances of this optimization method in terms of convergence characteristics. From the results it is observed that the feasible fuel cost is achieved in very less number of iterations which clears that the performance of TLA algorithm for solving NCEPD problem is better, in terms of quality of solutions obtained, compared to many already existing techniques.

5. Conclusion

The TLA method has been successfully implemented to solve non-convex EPD problem with the generator constraints. The teaching learning algorithm has the ability to find the better quality solution, has better convergence characteristics and computational efficiency. The non-linear characteristics of the generator such as valve-point loadings are considered for practical generator operation in the proposed method. It is clear from the results obtained that the proposed TLA method has good convergence property and can avoid the shortcoming of premature convergence of GA as well as PSO method to obtain better quality solution. Due to these properties, the TLA method in future can be tried to apply in complex unit commitment problems, dynamic EPD problems in the search of better quality results.

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