A NUMERICAL SOLUTION TO ECONOMIC LOAD DISPATCH PROBLEMS

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This paper presents a newly proposed Novel TANAN's Algorithm (NTA) for solving convex Economic Load Dispatch (ELD) problems considering transmission losses. The main objective of NTA is to minimize the total fuel cost of the generating units, subjected to limits on generator power output. The NTA is a simple numerical random search approach based on a parabolic TANAN function. This paper presents an application of NTA to ELD problems for different IEEE standard test systems. The simulation results show that the simplicity of the proposed algorithm with very less computational time.

Keywords: Optimization, Economic Load dispatch, Numerical method, TANAN function

1. Introduction

Engineering optimization problems contain more practical complex constraints. They can be formulated and solved as nonlinear programming models. The methods for solving these kinds of problems include traditional mathematical programming such as linear programming, quadratic programming, dynamic programming, gradient methods, Lagrangian relaxation and conventional methods like Taguchi Method(TM)[12] and Gravitational Search Algorithm(GSA)[17] approaches and modern meta-heuristic methods such as Genetic Algorithms(GA) [3],[15],[21], Evolutionary Programming(EP), Hop Field Neural Network(HNN)[18], Particle Swarm Optimization(PSO)[11],[13], Bacterial Foraging Optimization(BFO)[6], Artificial Bee Colony (ABC) [7],[14], Differential Evolution(DE) [9] and Biogeography-based optimization(BBO)[4] are some of these methods which are successful in locating the optimal solution but they are usually slow in convergence. Hybrid optimization techniques like Refined Genetic Algorithm (RGA) [5], Adaptive Tabu Search Algorithm (ATSA) [8], NPSO-LRS [10] and SOH-PSO [16] provides the solution with faster convergence. Some other methods may risk being trapped to a local optimum, which is the problem of premature convergence.

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Economic load dispatch is one of well-known problem in a field of power system optimization. The problem of dividing the total load demand among available online generators economically and also satisfying various system constraints simultaneously is called economic load dispatch. This is an important task in power system for allocating power generations among the committed units such that the constraints imposed are satisfied, the energy demands are met, and the corresponding cost is to be minimized.

Improvements in scheduling of the unit generations can lead to significant cost savings. In view of the nonlinear characteristics of this problem, there is a demand for the optimization methods that do not have restrictions on the shape of the fuel-cost curves. Although it does not guarantee the globally optimal solution in limited time, it does normally provide good solutions with computational cost. In the past decades, many optimization algorithms are tried with different kinds of constraints. In this paper a newly proposed Novel TANAN's Algorithm (NTA) is implemented to solve convex ELD problems.

2. Problem Formulation

The classical ELD problem is an optimization problem that determines the power output of each online generator that will result in a least cost system operating state. The objective of the classical economic dispatch is to minimize the total system cost where the total system cost is a function composed by the sum of the cost functions of each generator. This power allocation is done considering system balance between generation and loads, and feasible regions of operation for each generating unit.

The objective of the classical ELD is to minimize the total fuel cost by adjusting the power output of each of the generators connected to the grid. The total fuel cost is modelled as the sum of the cost function of each generator.

The basic economic dispatch problem can be described mathematically as a minimization of problem.

$$Minimise F_t = \sum_{i=1}^{n} F_i(P_i) \quad (1)$$

where $F_i(P_i)$ is the fuel cost equation of the 'i'th plant. It is the variation of fuel cost in \$ with generated Power (MW).

$$F_i(P_i) = \sum_{i=1}^{n} a_i P_i^2 + b_i P_i + c_i \quad (2)$$

The total fuel cost to be minimized is subject to the following constraints.

$$\sum_{i=1}^{n} P_i = P_d + P_l \tag{3}$$

$$P_L = \sum_{i=1}^{n}\sum_{j=1}^{n} P_i B_{ij} P_j + \sum_{i=1}^{n} B_{0i} P_i + B_{00} \tag{4}$$

$$P_i^{\min} \le P_i \le P_i^{\max} \tag{5}$$

3. Proposed Algorithm

Novel TANAN's Algorithm (NTA) [1], [2] is specially defined for solving economic dispatch problems. The algorithm is stated as follows. The TANAN function is given by

$$T_i = r_i + s_i x + t_i x^2 \tag{6}$$

With a power balance constraint

$$T_m = P_d + P_l - \sum_{\substack{t=1 \\ m \neq i}}^{n} T_i \tag{7}$$

where

Ti	- TANAN function
r_i, s_i & t_i	- coefficients of TANAN function
x	- TANAN function variable

The coefficients r_i, s_i and t_i have been assumed to be the minimum limit of i^{th} generator. The TANAN function variable 'x' is a random variable assumed to vary from 0 to 2.The value of each TANAN function is equivalent the power output of that particular generator. Since the TANAN function is a parabolic function, which has an extreme lowest point that corresponds to the optimum value of fuel cost.

3.1 Algorithm

Step1: Assign TANAN function to each generator.
Step2: Assign r_i, s_i and t_i values.
Step3: Initialize the value of x
Step4: Assign $P_i = T_i$.
Step5: If $P_i \le P_{imin}$ then fix $P_i = P_{imin}$ and if $P_i \ge P_{imax}$ then fix $P_i = P_{imax}$.
Step6: Verify P_d and generator constraints, if not adjust the value of x and

go to step 3.
Step7: If satisfied, notify the fuel cost values and stop the process.

4. Simulation Results

The NTA for ELD problems considering transmission losses has been implemented in MATLAB and it was run on a computer with Intel Core2 Duo 2.0 GHz processor, 3GB RAM memory and Windows XP operating system. After several runs, the following results were obtained and are tabulated from table 1 to table 3 along with previously published results and other algorithms.

Table 1

Best result for IEEE- 3 machine test system [19] with P_d = 850 MW

Description	Proposed NTA method	NTA method [1]	GA [15]
x	0.959	0.585	NA
P_1(MW)	421.199	575.942	399.64
P_2(MW)	287.868	192.723	320.80
P_3(MW)	143.934	96.361	146.18
Total power (MW)	853.001	865.026	866.62
Power loss (MW)	3.001	15.026	16.62
Total fuel cost ($/MW/h)	**8229.546**	8426.275	8349.58
Avg.simulation time (sec)	0.19	0.05	-

Table 2

Best result for IEEE- 15 machine test system with P_d=2640 MW

Description	Proposed NTA Method	NTA method [2]
x	**0.895**	0.747
P_1(MW)	404.404	448.431247
P_2(MW)	404.404	410.292150
P_3(MW)	128.868	54.705620
P_4(MW)	53.920	54.705620
P_5(MW)	404.404	410.292150
P_6(MW)	363.963	369.262935
P_7(MW)	363.963	369.262935
P_8(MW)	161.762	164.116860

P_9(MW)	67.401	68.382025
P_{10}(MW)	67.401	68.382025
P_{11}(MW)	53.920	54.705620
P_{12}(MW)	53.920	54.705620
P_{13}(MW)	67.401	68.382025
P_{14}(MW)	40.440	41.029215
P_{15}(MW)	40.440	41.029215
Total power (MW)	2676.611	2677.685262
Power loss (MW)	36.611	37.685262
Total fuel cost ($/MW/h)	**33270.906**	33389.662792
Avg.simulation time (sec)	0.45	0.007

Table 3

Best result for IEEE- 20 machine test system with P_d=2500 MW

Description	Proposed NTA Method (x=0.747)	Lambda Iteration method [18]	Hopfield Neural Network [18]
P_1(MW)	599.962	512.7805	512.7804
P_2(MW)	115.250	169.1033	169.1035
P_3(MW)	115.250	126.8898	126.8897
P_4(MW)	115.250	102.8657	102.8656
P_5(MW)	115.250	113.6836	113.6836
P_6(MW)	46.100	73.571	73.5709
P_7(MW)	57.625	115.2878	115.2876
P_8(MW)	115.250	116.3994	116.3994
P_9(MW)	115.250	100.4062	100.4063
P_{10}(MW)	69.150	106.0267	106.0267
P_{11}(MW)	230.501	150.2394	150.2395
P_{12}(MW)	345.751	292.7648	292.7647
P_{13}(MW)	92.200	119.1154	119.1155
P_{14}(MW)	46.100	30.834	30.8342
P_{15}(MW)	57.625	115.8057	115.8056
P_{16}(MW)	46.100	36.2545	36.2545

P_{17}(MW)	69.150	66.859	66.859
P_{18}(MW)	69.150	87.972	87.972
P_{19}(MW)	92.200	100.8033	100.8033
P_{20}(MW)	69.150	54.305	54.305
Total power (MW)	2582.270	2591.967	2591.967
Power loss(MW)	82.270	91.967	91.9669
Total fuel cost ($/MW/h)	**62136.184**	62456.64	62456.63
Avg.simulation time (sec)	0.09	-	-

6. Conclusions

The proposed NTA to solve ELD problem with the practical constraints has been presented in this paper. It is clear that the NTA is a simple numerical random search technique for solving ELD problems. From the simulations, it can be seen that NTA gave the best result with very less computational time. In future, the proposed NTA can be used to solve ELD considering ramp rate limits and prohibited operating zones and also for finding the optimal value of the NTA variable ‘x’ by developing standard search techniques.

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