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SOLUTION OF ECONOMIC LOAD DISPATCH PROBLEM INCLUDING LINE LOSSES USING BAT ALGORITHM

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ABSTRACT

Economic Load Dispatch (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 economic load dispatch is to minimize the total cost of each online generator .This power allocation is done considering system balance between generation and loads, and feasible regions of operation for each generating unit. This paper presents an effective and reliable BAT Algorithm for the economic load dispatch problem. The results have been demonstrated for ELD of standard 6-generator systems with consideration of transmission losses. The final results obtained using BAT Algorithm is compared with conventional quadratic programming (QP) and Genetic Algorithm (GA) found to be encouraging.

Keywords: Economic Load Dispatch, Transmission Losses, Quadratic Programming, GA, BAT Algorithm.

I. INTRODUCTION

Electrical power system operation should be characterized by security, reliability and economy. Economic Load Dispatch (ELD) which minimizes the operating cost is one of the most important operational planning problems. ELD is a method to schedule the power generator outputs with respect to the load demands, and to operate a power system most economically. Other characteristics of generating units that affect the ELD calculation are the minimum and maximum generation levels at which they may operate [1]. The problem of ELD is usually multimodal, discontinuous and highly nonlinear. Although the cost curve of thermal generating units are generally modelled as a smooth curve, the input-output characteristics are nonlinear by nature because of valve-point loading effects, Prohibited Operating Zones (POZ), ramp rate limits and so on[2].

Large steam turbine generators normally have multiple valves in steam turbines. The opening and closing of these valves are helpful to maintain the active power balance. However, this effect adds the ripples in the cost function. This effect is known as valve-point loading effect. Ignoring of valve-point loading effects leads to inaccuracy in the generation dispatch. Besides this, the generating units may have certain range where operation is restricted due to the physical limitation of machine component, steam valve, vibration in shaft bearing etc.

Such restricted regions of loading are commonly known as POZ. When a generating unit has POZ, its operating region breaks into isolated sub-regions, thus forms a nonconvex decision space. Furthermore, the operating range for online units is restricted by their ramp rate limits [3]. To keep thermal gradients inside the turbine within safe limits and to avoid shortening of life, the rate of increase or decrease of power output of generating units is limited within a range. Such ramp rate constraint makes the conventional ELD problem as a Dynamic Economic Dispatch (DED) problem. The presence of these nonlinearities in practical generator operation makes solving the ELD problem more challenging.

II. ECONOMIC LOAD DISPATCH FORMULATION

The fuel cost curve for any unit is assumed to be approximated by segments of quadratic functions of the active power output of the generator. For a given power system network, the problem may be described as optimization (minimization) of total fuel cost (1) as defined by under a set of operating constraints.

$$\sum_{i=1}^{n} F_i(P_{gi}) = a_i P_{gi}^2 + b_i P_{gi} + c_i \qquad (1)$$

Where F_i (P_{gi}) fuel cost of generation in the system ($/hr), and ai, bi, and ci are the cost coefficient of the ith Generator, Pi is the power generated by the i_{th} unit and n is the number of generators.

The cost is minimized subjected to the following generator capacities and active power balance constraints.

Load balance equation (2)

$$\sum_{i=1}^{N_g} P_{gi} - P_D - P_L = 0 \qquad (2)$$

Generation unit capacity limits (3)

$$P_{gi}^{min} \le P_{gi} \le P_{gi}^{max} \qquad (3)$$

The lower limit of the output power P_{gi}^{min} is the minimum economical loading limit below which the operation is infeasible technically and/or economically. On the other hand, P_{gi}^{max} represents the upper limit and the maximum output power. In order to obtain a more accurate loss formula, a linear term and a constant is added to the expression of (4) to form what is referred to as Kron's loss formula [4-9]:

$$P_L = \sum_{i=1}^{N_g}\sum_{j=1}^{N_g} P_{gi} B_{ij} P_{gj} + \sum_{i=1}^{N_g} B_{i0} P_{gi} + B_{00} \qquad (4)$$

The B-coefficients mainly depend on the operating condition of the system. They are usually assumed to be constant parameters, unless the system operating state of a new generation scheduling is significantly different from the base case [10-17].

III. PROPOSED METHODOLOGY

In this section, the solution procedure for the proposed BAT algorithm is described:

3.1 BAT Algorithm

The Bat algorithm was developed by Xin-She Yang in 2010 [18]. The algorithm exploits the so-called echolocation of the bats. The bats use sonar echoes to detect and avoid obstacles. It is generally known that sound pulses are transformed into a frequency which reflects from obstacles.

The bats navigate by using the time delay from emission to reflection. They typically emit short, loud sound impulses. The pulse rate is usually defined as 10 to 20 times per second. After hitting and reflecting, the bats transform their own pulse into useful information to gauge how far away the prey is. The bats are using wavelengths that vary in the range from 0.7 to 17 mm or in bound frequencies of 20-500 kHz. To implement the algorithm, the pulse frequency and the rate have to be defined. The pulse rate can be simply determined in the range from 0 to 1, where 0 means that there is no emission and 1 means that the bats' emitting is their maximum [19, 20, 21]**.** The bat behaviour can be used to formulate a new BA.Yang [22] used three generalized rules when implementing the bat algorithms:

1. All the bats use an echolocation to sense the distance and they also guess the difference between the food/prey and background barriers in a somewhat magical way.

2. When searching for their prey, the bats y randomly with velocity v_i at position x_i with fixed frequency fmin, varying wavelength λ and loudness A0 They can automatically adjust the wavelength (or frequency) of their emitted pulses and adjust the rate of pulse emission r ε [0, 1], depending on the proximity of their target.

3. Although the loudness can vary in many ways, we assume that it varies from a large (positive) A0 to a minimum constant value Amin

For simplicity, we do not use ray tracing in this algorithm, though it can form an interesting feature for further extension. In general, ray tracing can be computational extensive, but it can be a very useful feature for computational geometry another applications. Furthermore, a given frequency is intrinsically linked to a wavelength. For example, a frequency range of [20 kHz, 500 kHz] corresponds to a range of wave lengths from 0.7 mm to 17 mm in the air. Therefore, we can describe the change either in terms of frequency f or wave length λ to suit different applications, depending on the ease of implementation and other factors.

3.2 BAT Motion

Each bat is associated with a velocity and a location, at iteration t, in a d- dimensional search or solution space:

$$f_i = f_{\min} + \left(f_{\max} - f_{\min}\right)\beta \qquad (5)$$

$$v_i^t = v_i^{t-1} + \left(x_i^t - x_*\right) f_i \qquad (6)$$

$$x_i^t = x_i^{t-1} + v_i^t \qquad (7)$$

Where β ε [0, 1] ,is a random vector drawn from a uniform distribution. As mentioned earlier, we can either use wavelengths or frequencies for implementation, we will use fmin= 0 and fmax = O (1), depending on the domain size of the problem of interest. Initially, each bat is randomly assigned a frequency which is drawn uniformly from [fmin, fmax]. For this reason, bat algorithm can be considered as a frequency-tuning algorithm to provide a balanced combination of exploration and exploitation [23-25]. The loudness and pulse emission rates essentially provide a mechanism for automatic control and auto zooming into the region with promising solutions.

3.3 Pseudo Code of BAT Algorithm

Objective function f(x), x = (x1,...., xd)^{T}Initialize the bat population xi and v_i for i = 1.....nDefine pulse frequency Q_i ε [Qmin, Qmax]Initialize pulse rates r_i and the loudness A_iWhile (t < T_{max}) number of iterations Generate new solutions by adjusting frequency and update velocities and locations/solutions. If (rand (0; 1) > r_i) [Eq. (5) to (7)]Select a solution among the best solutions Generate a local solution around the best solution end if Generate a new solution by flying randomlyif (rand (0; 1) < Ai and f(xi) < f(x))Accept the new solutions Increase ri and reduce Aiend ifRank the bats and find the current best X_*end whilePost process results and visualization

IV. CASE STUDY-1: 6-UNITS SYSTEM

In this case, a simple power system consists of six-unit thermal power plant is used to demonstrate. Characteristics of thermal units are given in Table 1, the following coefficient matrix Bij losses [2].

Table: 1 Characteristics of Thermal units

Unit	P_i^{min} (MW)	P_i^{max} (MW)	a_i (\$/MW^2)	b_i (\$/MW)	c_i (\$)
1	10	125	0.15240	38.53973	756.79886
2	10	150	0.10587	46.15916	451.32513
3	35	225	0.02803	40.39655	1049.9977
4	35	210	0.03546	38.30553	1243.5311
5	130	325	0.02111	36.32782	1658.5596
6	125	315	0.01799	38.27041	1356.6592

$$B_{ij} = \begin{bmatrix} 0.000140 & 0.000017 & 0.000015 & 0.000019 & 0.000026 & 0.000022 \\ 0.000017 & 0.000060 & 0.000013 & 0.000016 & 0.000015 & 0.000020 \\ 0.000015 & 0.000013 & 0.000065 & 0.000017 & 0.000024 & 0.000019 \\ 0.000019 & 0.000016 & 0.000017 & 0.000071 & 0.000030 & 0.000025 \\ 0.000026 & 0.000015 & 0.000024 & 0.000030 & 0.000069 & 0.000032 \\ 0.000022 & 0.000020 & 0.000019 & 0.000025 & 0.000032 & 0.000085 \end{bmatrix}$$

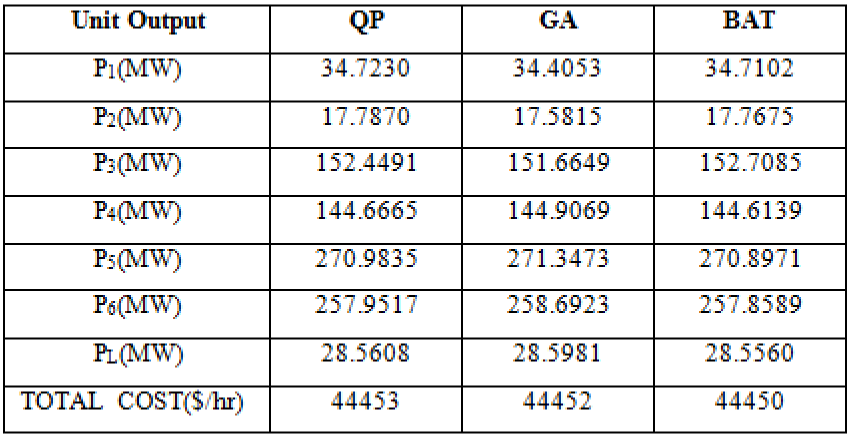
V. SIMILATION RESULTS AND DISCUSSION

The applicability and validity of the BAT algorithm for practical applications has been tested on six unit thermal power plant. The obtained best solution in fifty runs are compared with the results obtained using GA and Quadratic Programming (QP). All the programs are developed using MATLAB 7.8.0 (2009a) and the system configuration is core i3 processor with 2.30 GHz speed and 3 GB RAM. The Parameters for BAT algorithm considered here are:

n=20; A=0.9; r=0.1; fmin= 0; fmax= 2. The proposed BAT algorithm stopping criteria is based on maximum generation=100

Table: 2 show the summarized result of all the existing algorithms along with BAT algorithm for test case. Form Table: 2, it is clear that BAT algorithm gives optimum result in terms of minimum fuel cost compared to other existing algorithms shown for power demand of 850 MW. It shows that the technique converges in relatively fewer cycles thereby possessing good convergence property.

Table: 2 Comparison of results for test case (PD=850 MW)



Unit Output	QP	GA	BAT
P_1(MW)	34.7230	34.4053	34.7102
P_2(MW)	17.7870	17.5815	17.7675
P_3(MW)	152.4491	151.6649	152.7085
P_4(MW)	144.6665	144.9069	144.6139
P_5(MW)	270.9835	271.3473	270.8971
P_6(MW)	257.9517	258.6923	257.8589
P_L(MW)	28.5608	28.5981	28.5560
TOTAL COST($/hr)	44453	44452	44450

VI. CONCLUSION

In this paper, a BAT algorithm has been proposed. In order to prove the effectiveness of algorithm it is applied to economic load dispatch problem with six generating units. The results obtained by proposed method were compared to those obtained by conventional quadratic programming and Genetic Algorithm (GA). The comparison shows that BAT algorithm performs better than above mentioned methods. The BAT algorithm has superior features, including quality of solution, stable convergence characteristics and good computational efficiency. Therefore, this results shows that BAT optimization is a promising technique for solving complicated problems in power system.

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