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Application of Computational Intelligence for Solving Economic Load Dispatch Problem

Hardiansyah[1], Eko Sarwono[2]
[1] *(Department of Electrical Engineering, University of Tanjungpura, Indonesia)*
[2] *(Department of Mechanical Engineering, University of Muhammadiyah Pontianak, Indonesia)*

Abstract: *This paper presents the application of computational intelligence for solving economic load dispatch (ELD) problem. A novel hybrid particle swarm optimization and gravitational search algorithm (PSO-GSA) is employed to ELD problem so as to minimize the total generation cost when considering the linear and non linear constraints. To illustrate the effectiveness of the proposed algorithm, a standard of six-unit thermal power plant (IEEE 30 bus test system) is used. The results show the effectiveness and the superiority of the proposed method over other methods.*

Keywords: *Particle swarm optimization, gravitational search algorithm, economic load dispatch, hybrid PSO-GSA.*

I. Introduction

The electric utility systems are interconnected in such a way to achieve the benefits of minimum production cost, maximum reliability and better operating conditions. The ELD problem is one of the fundamental issues in power system operation and control. The ELD problem finds the optimum allocation of load among the committed generating units subject to satisfaction of power balance and capacity constraints, such that the total cost of operation is kept at a minimum. Due to ELD complex and nonlinear characteristics, it is hard to solve the problem using classical optimization methods.

Most of classical optimization techniques such as lambda iteration method, gradient method, Newton's method, linear programming, Interior point method and dynamic programming have been used to solve the basic economic dispatch problem [1]. The practical ELD problem is represented as a non-convex optimization problem with equality and inequality constraints, which cannot be solved by the traditional mathematical methods. Over the past few decades, as an alternative to the conventional mathematical approaches, many salient methods have been developed for ELD problem such as evolutionary programming (EP) [2], biogeography-based optimization (BBO) [3], particle swarm optimization (PSO) [6, 7], differential evolution (DE) [8], and gravitational search algorithm (GSA) [9].

PSO is a stochastic algorithm that can be applied to nonlinear optimization problems. PSO has been developed from the simulation of simplified social systems such as bird flocking and fish schooling by Kennedy and Eberhart [4, 5]. The main difficulty classic PSO is its sensitivity to the choice of parameters and they also premature convergence, which might occur when the particle and group best solutions are trapped into local minimums during the search process. One of the recently improved heuristic algorithms is the gravitational search algorithm (GSA) based on the Newton's law of gravity and mass interactions. GSA has been verified high quality performance in solving different optimization problems in the literature [10]. The same goal for them is to find the best outcome (global optimum) among all possible inputs. In order to do this, a heuristic algorithm should be equipped with two major characteristics to ensure finding global optimum. These two main characteristics are exploration and exploitation [11].

In this paper, a hybrid PSO-GSA technique is presented and applied to solve the ELD problem considering the power transmission loss. The performance of the proposed technique is tested on a six-unit system.

II. Problem Formulation

The objective of the ELD problem is to find the optimal combination of power generations that minimizes the total generation cost while satisfying equality and inequality constraints. ELD can be expressed as an objective optimization problem with various complicated constraints as follow:

Minimize $$F_T = \sum_{i=1}^{n} F_i(P_i) = \sum_{i=1}^{n} \left(a_i P_i^2 + b_i P_i + c_i \right) \tag{1}$$

Subject to

$$\sum_{i=1}^{n} P_i - P_D - P_{Loss} = 0 \qquad (2)$$

$$P_i^{\min} \le P_i \le P_i^{\max} \ \text{ for } \ i = 1,2,\cdots,n \qquad (3)$$

Where

$$P_{Loss} = \sum_{i=1}^{n}\sum_{j=1}^{n} P_i B_{ij} P_j \qquad (4)$$

F_T is total fuel cost of generation in the system ($/hr), a_i, b_i, and c_i are the cost coefficient of the *i*-th generator, P_i is the power generated by the *i*-th unit and *n* is the number of generators. P_D is the total load demand and P_{Loss} is total transmission losses. $P_i^{\min}$ and $P_i^{\max}$ are the minimum and maximum outputs of the *i*-th generator, respectively.

III. Hybrid PSO-GSA

The basic idea of PSO-GSA method is to combine the ability of social thinking (*gbest*) in PSO with the local search capability of GSA. In order to combine these algorithms, the updated velocity of agent *i* can be calculated as follows:

$$V_i(t+1) = w \times V_i(t) + c_1 \times rand_i \times a_i(t) + c_2 \times rand_i \times \left(gbest - X_i(t)\right) \qquad (5)$$

where V_i(t) is the velocity of agent *i* at iteration *t*, c_j is a weighting factor, *w* is a weighting function, *rand* is a random number between 0 and 1, a_i(t) is the acceleration of agent *i* at iteration *t*, and *gbest* is the best solution so far.

The position of the particles at each iteration updated as follow:

$$X_i(t+1) = X_i(t) + V_i(t) \qquad (6)$$

The process of the proposed PSO-GSA algorithm can be summarized as the following steps:

Step 1 Get the data for the system,
Step 2 Generate initial population,
Step 3 Fitness evaluation of agents,
Step 4 Update *G(t)* and *gbest(t)*,
Step 5 Calculation of the mass of the object, gravitational constant, the total force, and acceleration,
Step 6 Updating agents' velocity and position,
Step 7 Repeat step 3 to step 6 until the stop criteria is reached,
Step 8 Stop.

IV. Simulation Results And Discussion

In this section, a standard of six-unit thermal power plant (IEEE 30 bus test system) is used to demonstrate how the work of the proposed technique. Characteristics of thermal units are given in Table I, the followed by coefficient matrix B_{ij} losses [12].

Table I Generating unit capacity and coefficients

Unit	$P_i^{\min}$ (MW)	$P_i^{\max}$ (MW)	a_i ($/MW^2)	b_i ($/MW)	c_i ($)
1	10	125	0.0033870	0.856440	16.817750
2	10	150	0.0023500	1.025760	10.029450
3	35	225	0.0006230	0.897700	23.333280
4	35	210	0.0007880	0.851234	27.634000
5	130	325	0.0004690	0.807285	36.856880
6	125	315	0.0003998	0.850454	30.147980

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

The simulation result with the proposed technique is shown in Table II with the load of 700 MW. From the simulation results show that the generation output of unit is obtained correction reduces the total cost of generation and transmission losses when it compared with the PSO and GSA. The convergence characteristic of proposed technique is provided in Figure 1.

Table II Best solution for 6-generator system (P_D = 700 MW)

Unit Output	PSO	GSA	PSOGSA
P1 (MW)	39.8172	23.9777	28.2991
P2 (MW)	28.8558	39.9700	10.0000
P3 (MW)	113.9936	99.8958	118.9327
P4 (MW)	65.3541	91.8257	118.6700
P5 (MW)	250.7677	215.0290	230.8054
P6 (MW)	220.7384	248.8123	212.7250
Total power output (MW)	719.5272	719.5105	**719.4322**
Total generation cost ($/hr)	824.4418	824.3882	**820.2665**
Power losses (MW)	19.5272	19.5105	**19.4322**
CPU time (sec)	2.7984	0.7132	**0.6867**

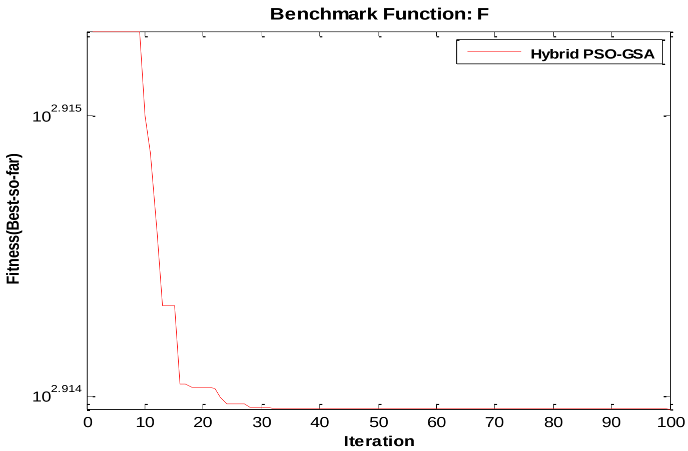

Figure 1 Convergence characteristic of hybrid PSO-GSA

V. Conclusion

A new hybrid PSO-GSA technique has been successfully implemented to solve ELD problems with the generator constraints as linear equality and inequality constraints and also considering transmission loss. The algorithm is implemented for six-unit system. From the result, it is clear that the proposed algorithm has the ability to find the better quality solution and has better convergence characteristics, computational efficiency and less CPU time per iteration when compared to other methods such as PSO and GSA.

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