An Efficent Particle Swarm Optimisation (Epso) For Solving Economic Load Dispatch (Eld) Problems

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ABSTRACT

The scope of this paper is to focus on cost effective, reliable and eco-friendly operation of power system. Power is key to economic development of any country especially fast developing countries like India. In the global environment, no country can be competitive unless, it has adequate and affordable power availability. Economic load dispatch is vital component in the operation of power system & flow of power from generation point to the distribution point. Most of electrical power utilities in the world are required to ensure that electrical energy requirement from the customer is served smoothly in accordance to the respective policy of the country. Despite serving the power demands of the country, the power utility has also to ensure that the electrical power is generated within minimal cost. Thus, the total demand must be appropriately shared among the generating units with an objective to minimize the total generation cost of the system in order to satisfy the economic operation of the system. Economic dispatch is a procedure to determine the electrical power to be generated by the committed generating units in a power system so that the total generation cost of the system is minimized, satisfying the load demand simultaneously. This paper presents the solution to a certain extent of economic load dispatch (ELD) problems using Efficient Particle Swarm Optimization (EPSO) .The Particle Swarm Optimization (PSO) is a relatively recent heuristic search method whose mechanics are inspired by the swarming or collaborative behaviour of biological populations [1].

Keywords – AI, Economic Load Dispatch, Efficient Particle Swarm Optimization (EPSO), GA method**,** Lambda iteration method.

1. INTRODUCTION

Electricity is modern society's most convenient and useful form of energy. The increasing per capita consumption of electricity throughout the world reflects a growing living standard of people while demand has increased the need for a cost effective, reliable and eco-friendly steady power supply with minimum power interruption, and fast fault restoration. The efficient and optimum economic operation and planning of electric power generation systems have always occupied an important position in the electric power industry [2]. Scarcity of energy resources, increasing power generation cost, and ever growing demand for electric energy necessitate optimal economic dispatch (ED) in today's electric power systems. ED operation is performed at the energy management center every few minutes to allocate the optimal real power generation to the committed generators in a power network in such a way that the cost of operation becomes minimum while all other operating constraints are satisfied [3]. Various kinds of optimization techniques have been applied to solve ELD problems. The various techniques are classified into two groups:

Classical optimization techniques: **-** such as the Lambda-iteration Method [2,4], the Base Point and Participation Factor Methods [2,4], the Gradient Method [2,4], and the Newton Method [2,4]

1.1. **Artificial Intelligent (AI)-based optimization techniques**:**-** such as the Tabu Search(TS)[7],the PSO[5,13,10] & the GA[6,7,11,12].

However, the methods include an essential assumption: the incremental costs of the generators are monotonically increasing and piecewise-linear functions [2].

In the past decade, conventional optimization techniques such as Lambda iterative method, linear programming and quadratic programming have been successfully used to solve power system optimization problems such as Unit commitment, Economic load dispatch, Feeder reconfiguration and Capacitor placement in a distribution system. For non-linear and combinational optimization problems, the conventional methods are facing difficulties to locate the global optimal solution. Now days there is an upsurge in the use of modern evolutionary computing techniques in the field of power system optimization. The Genetic algorithm (GA) method, Evolutionary programming, Evolution strategy and simulated annealing are some of the well known evolutionary algorithms [8, 12]. Though the GA method has been employed successfully to solve complex optimization problems, recent research has identified some deficiencies in GA performance. This degradation in efficiency is apparent in applications with highly epispastic objective functions (i.e where the parameters being optimized are highly correlated). The crossover and mutation operations cannot ensure better fitness of offspring because chromosomes in the population have similar structures and their average fitness is high towards the end of the evolutionary process. Moreover, the premature convergence of GA degrades its performance and reduces its search capability that leads to a higher probability for obtaining a local optimum [9].

One of the evolutionary algorithms that have shown great potential and good perspective for the solution of various optimization problems is EPSO.

The EPSO technique can generate high-quality solutions within shorter calculation time and stable convergence characteristics than other stochastic methods [5].

This paper proposes the application of EPSO method for solving the economic load dispatch problems of three unit power system.

2. MATHEMATICAL MODEL OF THE ECONOMIC DIAPATCH PROBLEM

2.1 Basic Concept of Economic Dispatch Formulation

The Economic Load Dispatch (ELD) is used to find the optimal combination of generators output so as to minimize the total fuel cost satisfying several constraints. The problem is to minimize the total fuel cost which is formulated as the sum of the cost function of each generator, which must satisfy the objective function:

Mathematically it can be represented as [2]

Minimize: $F_t = \sum_{i=1}^{n} F_i P_i$ ………………………..1

Where $F_t = \sum_{i=1}^{n} A_i P_i^2 + B_i P_i + C_i$…………. 2

1) *Real Power Balance Equation*

The power balance equation,

$\sum_{i=1}^{NG} P_{gi} = P_D + P_L$……………………………….3

The total Transmission loss,

$P_L = \sum P_m B_{mn} P_n$………………………………….4

2) *Unit Operating Limits*

There is a limit on the amount of power which a unit can deliver. The power output of any unit should neither exceed its rating nor it should be below that is necessary for stable operation. Generation output of each unit should lie between maximum and minimum limits. The corresponding inequality constraints for each generator are;

$$P_{gi}^{min} \le P_{gi} \le P_{gi}^{max},$$
$$for\ i = 1,2,3,4,5,6,7,8 \dots \dots \dots n$$

3. EFFICENT PARTICLE SWARM OPTIMIZATION(EPSO)

Particle swarm optimization (PSO) is a population based stochastic optimization technique developed by Dr. Ebert and Dr. Kennedy in 1995, inspired by social behaviour of bird flocking or fish schooling [5]. Suppose the following scenario: a group of birds are randomly searching food in an area. There is only one piece of food in the area being searched. All the birds do not know where the food is. But they know how far the food is in each iteration, so what's the best strategy to find the food. The effective one is to follow the bird, which is nearest to the food. PSO learned from the scenario and used it to solve the optimization problems. In PSO, each single solution is a "bird" in the search space. We call it "particle". All particles have fitness values, which are evaluated by the fitness function to be optimized, and have velocities, which direct the flying of the particles. The particles fly through the problem space by following the current optimum particles.

Let *x* and *v* denote a particle co-ordinate and its corresponding flight speed in a search space respectively. Therefore, each i^{th} particle is treated as a volume less particle, represented as $x_i = (x_{i1}, x_{i2} \dots x_{id})$ in the d-dimensional space. The best previous position of the ith particle is recorded and represented as $p_{besti} = (p_{besti1}, p_{besti2}, \dots\dots p_{bestid})$.The index of the best particle among all the particles is treated as global best particle and is represented as g_{bestd}. The rate of velocity for particle 'i' is represented as $v_i = (v_{i1}, v_{i2} \dots\dots v_{id})$.The modified velocity and position of each particle can be calculated using the current velocity and the distance from p_{bestid} to g_{bestd} as shown in the following formulas,

$V_{id}^{(t+1)} = \omega V_i^{(t)} + C_1 rand()(pbest_{id} - P_{gid}^{(t)}) + C_2 Rand()(gbest_{id} - P_{gid}^{(t)})$………………5

$P_{gid}^{(t+1)} = P_{gid}^{(t)} + V_{id}^{(t+1)}$……………………6

In the above equation,

C_1 is called self-confidence range; (1.5, 2)

C_2 is called swarm range; (2, 2.5)

Rand ( )*($g^{best}{}_d$-$P_{gid}^{(t)}$) is called swarm influence

$v_i^{(t)}$ is the velocity of i^{th} particle at iteration't' must lie in the range $V_d^{min} \le v_{id}^{(t)} \le V_d^{max}$

V_d^{max} was often set at 10-20% of the dynamic range on each dimension

In general, the inertia weight ω is set according to the following equation:

$\omega = \omega_{max} - \frac{\omega_{max} - \omega_{min}}{iter_{max}} \times iter$ …………7

Where,

ω - Inertia weight factor

ω_{min} - maximum value of weighting factor

ω_{max} - minimum value of weighting factor

$iter_{max}$ - maximum number of iterations

iter - current number of iteration

The following property of EPSO explains its advantages:

• Generally good at finding acceptable solutions to a problem reasonably quickly
• Free of mathematical derivatives
• No gradient information is required
• Free of restrictions on the structure of the evaluation function
• Fairly simple to develop
• Do not require complex mathematics to execute
• Able to vary not only the values, but also the structure of the solution
• Get a good set of answers, as opposed to a single optimal answer
• Make no assumptions about the problem space
• Blind without the fitness function. The fitness function drives the population toward better
• Solutions and is the most important part of the algorithm.
• Not guaranteed to find the global optimum solutions
• Probability and randomness are essential parts of GA
• Can by hybridized with conventional optimization methods
• Potential for executing many potential solutions in parallel
• Deals with large number of variables
• Provides a list of optimum variables

4. IMPLEMENTATION OF THE EFFICENT PARTICLE SWARM OPTIMIZATION ALGORITHM FOR ECONOMIC DISPATCH PROBLEM

The EPSO algorithm was utilized mainly to determine the optimal allocation of power among the units, which were scheduled to operate at the specific period, thus minimizing the total generation cost. Any optimization process is applied to the ELD problem considering some constraints.

In this work two different constraints are considered. Among them the equality constraint, summation of all the generating power must be equal to the load demand and the inequality constraint, the powers generated must be within the limit of maximum and minimum active power of each unit.

In this work economic load dispatch problem considered, can be classified in two different ways.
1. Economic load dispatch without considering the transmission line losses
2. Economic load dispatch considering the transmission line losses.

RESULT ANALYSIS AND DISCUSSION

Three unit Power system results of EPSO and Genetic Algorithm (GA) are compared with the Lambda Iteration method. In the first case transmission losses are neglected.
The cost characteristics of the three units

$$F_1 = 0.00156P_1^2 + 7.92P_1 + 561\ Rs/Hr.$$
$$F_2 = 0.00194P_2^2 + 7.85P_2 + 310\ RS/Hr.$$
$$F_3 = 0.00482P_3^2 + 7.97P_3 + 78\ RS/Hr.$$

The unit operating ranges are:
$100 \leq P_1 \leq 600\ MW$
$100 \leq P_2 \leq 400\ MW$
$50 \leq P_3 \leq 200MW$

For minimum cost optimum solution:

$$\frac{dF_1}{dP_1} = 7.92 + 0.00124P_1 = \lambda$$
$$\frac{dF_2}{dP_2} = 7.85 + 0.00388P_2 = \lambda$$
$$\frac{dF_3}{dP_3} = 7.97 + 0.00964P_3 = \lambda$$

For the system loads of P_D= 450MW, 858MW, 700MW, 800MW, 900MW

EPSO Method Parameters:
$c_1 = c_2$ =2.01
Population size = 10
The maximum value of w is chosen 0.9 and minimum value is chosen 0.4

GA Method Parameters
Chromosomes size =10
string length =10
Crossover operation =0.8

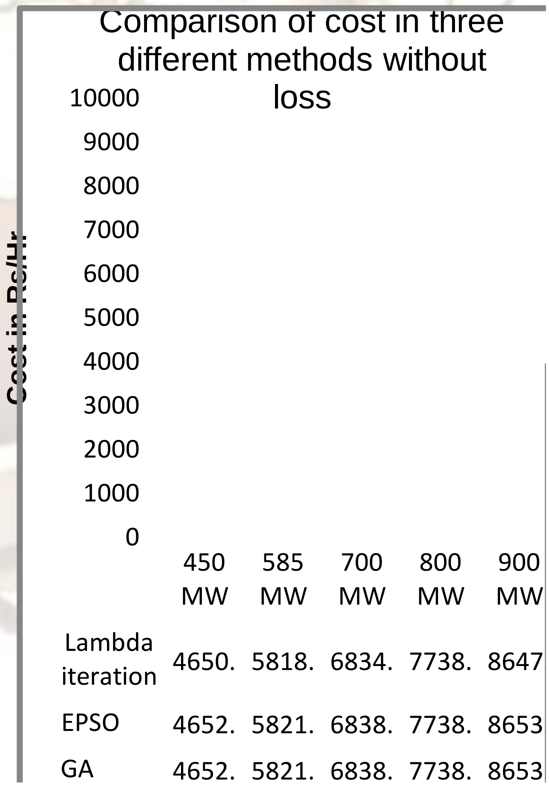
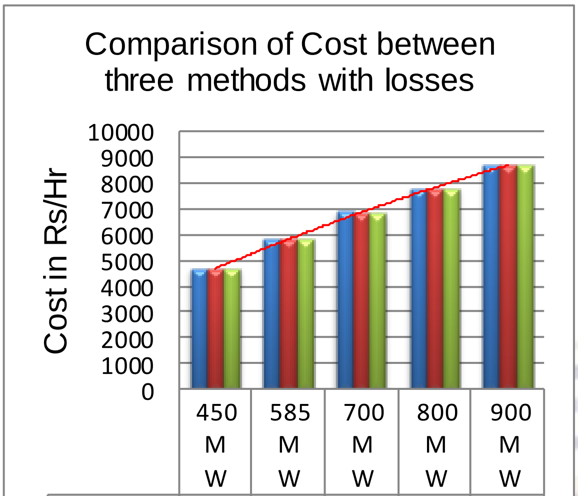


Table 1: Comparison of cost in three different methods without loss



	450 MW	585 MW	700 MW	800 MW	900 MW
Lambda iteration	4665	5845	6872	7783	8712
EPSO	4664	5842	6869	7779	8706
GA	4664	5842	6869	7779	8706

FIG 2: Comparison of cost in three different methods with loss

5. CONCLUSION

Lambda-iteration Method used for Economic Load Dispatch is better but the problem converges when the Lambda value is selected within the feasible range. The cost characteristic takes much number of iterations to converge. In EPSO and GA method for ELD problem, the cost characteristic converges in less number of iterations. The EPSO method was successfully employed to solve the ELD problem with all the constraints. The EPSO algorithm has been demonstrated to have superior features including high quality solution, stable convergence characteristics, and less computation time. Many non-linear characteristics of the generators can be handled efficiently by the proposed method. The comparison of results for the test cases clearly shows that the proposed method was indeed capable for obtaining higher quality solution efficiently for ELD problems.

LIST OF ABBREVIATIONS AND SYMBOLS

Abbreviations

ED Economic dispatch
GA Genetic algorithm
PSO Particle swarm optimization
ELD Economic load dispatch
EPSO Efficient Particle swarm optimization
TS Tabu search

Symbols

F_t - Total fuel cost
N - Number of online generators committed to the operating system
P_i - Power output of i^{th} generator.
$F_i(P_i)$ - Fuel cost characteristics of the i^{th} generator
P_D -Total power demand
P_L - Total transmission loss
B_{mn} - Co-efficient of Transmission loss formula.
$P_{i\ max}$ - Maximum generation capacity of the i^{th} generator
P_{imin} - Minimum generation capacity of the i^{th} generator.
n - Number of particles in a group
m - Number of members in a particle
t - Pointer of iterations (generations)
ω - Inertia weight factor
C_1, C_2- Acceleration constant
rand(), rand() - Uniform random value in the range [0,1]
$V_{id}^{(t)}$- velocity of particle i at iteration‘t’,
$V_d^{min} \leq V_{id}^{(t)} \leq V_d^{max}$
$X_{id}^{(t)}$- current position of particle i at iteration‘t’
A_i, B_i, C_i - Fuel cost coefficients

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