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Solution of Economic Load Dispatch Problems with Improved Computational Performance using Particle Swarm Optimization

Ravinder Singh Maan[1], Om Prakash Mahela[2], Mukesh Gupta[3]
[1](*Assistant Professor, Dept. of Electrical Engineering, Jaipur National University, Jaipur, India)*
[2](*Graduate Student Member IEEE & Junior Engineer-I, RRVPNL, Jaipur, India)*
[3](*Assistant Professor, Department of Electrical Engineering, JNIT Jaipur, India)*

ABSTRACT : *This paper presents an algorithm using particle swarm optimization (PSO) technique to solve economic load dispatch (ELD) problems with improved computational efficiency. The PSO technique is used because it consumes less computation time (C.P.U.) as compared to genetic algorithm (GA).The PSO technique takes less computational time per iteration. This paper also presents comparison of the cost in Rs. / hr. to C.P.U. time with equal swarm size and equal number of iteration for 15 runs as well as the solution for the convergence of the particle in search space to the global best solution point after some iteration. The solution for the C.P.U. time with different size and equal number of iteration is also presented. The PSO algorithm solves the problems with fast parameters changes as compared to other algorithm. The simulation results showthe performanceof the PSO technique for solving the economic load dispatch problem.*

KEYWORDS:*Computational efficiency, economic load dispatch, genetic algorithm, particle swarm optimization,*

I. INTRODUCTION

Most of power system optimization problems including economic load dispatch have complex and nonlinear characteristics with large equality and inequality constraints. The Particle Swarm Optimization is the best technique to solve optimization problems with less computational time for different number of iteration.The particle swarm optimization has better computational efficiency and population based technique developed by Kennedy and Eberhart in 1995 [1]. There are some parameters e.g., acceleration constants c_1&c_2, the inertia weight$w$, maximum velocity v_{max}, constriction factor and swarm size used in PSO technique [2]. The particle is defined as each candidate in PSO with randomized velocity, moves in a solution space. The PSO is called best solution technique because of less computational time, robust, fast for solving multi-optimal problems and also to solve non-linear optimization problems. The acceleration constants are c_1&$c_2$set for 2.0 for all application. The swarm size is almost common and widely used is 20-50[2]-[3].

The particle swarm optimization can apply to various problems and easy to apply as compared to other conventional methods [4]. The PSO technique is based on the social behaviour of fish schooling and bird flocking [5]. To solve unconstrained and constrained problems the PSO technique is most powerful method [6]. The velocity of each particle is updated by the velocity equation which is used in the previous velocity [7].In this paper, the velocity and position of the particle is updated using the velocity and position equations respectively. The PSO algorithm is also used to solve multimodal problems. The most advantage of the PSO method is that it is fast convergent speed method. In PSO method, we need less number of parameters for adjustment [8]. The PSO is used as a heuristic *global* optimization technique. The particle swarm optimization algorithm is used without any mass and volume of any particle [9]. The PSO is a powerful technique to solve economic load dispatch (ELD) problems with less computational time as compared to other methods [10]. The PSO technique is also applied to solve ELD problems which are very complex and non-linear problem. Economic load means minimization of fuel cost or generating cost with fewer amounts of losses and higher power outputs [4].

II. PARTICLE SWARM OPTIMIZATION

PSO is similar to another optimization technique with a population of random solution space. In the proposed study the terms $pbest$ and $gbest$ have been used. The $pbest$ is the personal best and it is defined as the best previous position giving the best fitness value of the i^{th} particle but not in a group of particles.The g$best$is defined as best optimization solution in a swarm. There is some important key terminology related to PSO and defined as:

Particle/agent: The single individual (bees) in a swarm

pbest:Individual position of a particle
gbest: Individual position of a particle for the entire swarm
$\mathbf{v_{max}}$**:** The maximum velocity in a given direction
Location/position: Theparticle n-dimensional coordinates
Swarm: The entire area covered by the particle
Fitness: The goodness value of the particle
The important steps used in the Particle Swarm Optimization Technique for the solution of complex problems are as given below:
Step 1: Describes the solution space.
Step 2: Define the fitness value.
Step 3: Initialize Swarm velocity and position.
Step 4: Find the pbest and gbest solution
Step 5: Update the particle velocity and position.
Step 6: Repeat the process and find the stop criteria.
The velocity of the particle is changed according to following equation:

$$V_n = \omega v_n + c_1 rand_1 \times (pbest, n - x_n) + c_2 rand_2 \times (gbest, n - x_n) \ldots\ldots\ldots\ldots (1)$$

Where,
$\boldsymbol{v_n}$= Particle velocity in the n^{th} dimensional search space
$\boldsymbol{x_n}$= Particle coordinates in n^{th} dimensional search space
$\boldsymbol{\omega} =$ Inertia weight
$\boldsymbol{c_1}$**and**$\boldsymbol{c_2}$ =Two positive acceleration constants
$\boldsymbol{rand_1}, \boldsymbol{rand_2} =$ The random number functions between 0.0 to 1.0. The new coordinate is computed for each dimension by following equation:

$$X_n = x_n + \Delta t \times V_n \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

The early work done using the PSO uses$c_1 \& c_2$ for eachiteration. In the proposed study the inertia weightvarying linearly from 0.9 to 0.4 over the run time has also been used.

III. PROBLEM FORMULATION OF ECONOMIC DISPATCH USING PSO

The main objective is minimization of generating cost with low power losses, less computational time and higher generating output. The power inequalities specified in the equation (3) are satisfied while optimization of objective functions.

$$P_i^{min} \leq P_i \leq P_i^{max} \; (i = 1, \ldots\ldots n_g) \ldots\ldots\ldots (3)$$

Where,
P_i^{min}, P_i^{max} are the minimum and maximum generating limits for plant$\boldsymbol{i}$.
The total power losses as function of B-coefficients is given by the equation (4)
,

$$P_L = \sum_{i=1}^{n_g} \sum_{j=1}^{n_g} P_i B_{ij} P_j \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

The total generating cost is defined as given in equation (5).

$$C_t = \sum_{i=1}^{n_g} C_i (P_i) = \sum_{i=1}^{n_g} \alpha_i + \beta_i P_i + \gamma_i P_i^2 \ldots (5)$$

Where,
$\boldsymbol{C_i} =$ Cost function
$\boldsymbol{\alpha_i}, \boldsymbol{\beta_i}, \boldsymbol{\gamma_i} =$ Cost coefficient of the i^{th}generator
$\boldsymbol{n_g} =$ Total generating plants
$\boldsymbol{P_i}$= The output of the i^{th} Plant

From the solution, we find temporary variable which store the $gbest$ value. We also find the elapsed time or program run time with PSO algorithm. The minimum generating cost rate to meet the load demand with satisfying constraints can be obtained by optimization of cost function given in equation (5) as given in equation (6).

$$MinC_t = \sum_{i=1}^{n_g} C_i (P_i) = \sum_{i=1}^{n_g} \alpha_i + \beta_i P_i + \gamma_i P_i^2 \ldots\ldots\ldots\ldots (6)$$

IV. SIMULATION RESULTS AND DISCUSSION

In the proposed study, the PSO algorithm is used with less computational time. The PSO algorithm is also used for the multi-dimensional problem solutions. The economic load dispatch is the optimization problem which is solved using PSO technique with less computational time and number of reasonable iterations The PSO algorithm is implemented using Matlab software with high speed. The program is run for 15 trials with equal number of swarm size and iteration. The values of the accelerations constant $c_1 \& c_2$ for standard PSO are set as $c_1 = c_2$ =2.0. The results of computational time with different swarm size are obtained. We also compared the PSO technique with the GA technique in CPU time/ iteration. Finally we observed that the PSO technique requires less computational time as compared to the other optimization technique.

The comparison of CPU computational time and generation cost in Rs/hr for different swarm sizes and same number of iterations is shown in Table 1. Results show that the computational time as well as generation cost decreases with decreasing the swarm size. The comparison of computational time and generation cost in Rs./hr for same number of iteration and same swarm size with repetitive running of Matlab program is shown in Table 2. The comparison of computational time and generation cost in Rs/hr. for PSO and GA methods for different iterations are shown in Table 3. The results show the superiority of PSO method as compared to the GA method. The computational time as well as the cost is less for PSO method as compared to the GA method.

Table 1 Comparison of Computation Time and Cost by Varying Swarm Size for Pso

S.No.	Swarm Size	No. of Iteration	C.P.U. Time	Cost (Rs./hr)
1	1000	15	0.887627	15261
2	500	15	0.717794	15273
3	250	15	0.690525	15282
4	125	15	0.686076	15293
5	75	15	0.671597	15328

Table 2 Comparison of Computational Time and Cost for 15 Runs

S.No.	Nos. of Iteration	Swarm Size	C.P.U. Time	Cost in Rs./Hr
1	15	1000	0.804125	15268
2	15	1000	0.794473	15288
3	15	1000	0.794712	15386
4	15	1000	0.789600	15371
5	15	1000	0.793976	15320
6	15	1000	0.730424	15287
7	15	1000	0.781664	15361
8	15	1000	0.780308	15278
9	15	1000	0.803883	15295
10	15	1000	0.798119	15268
11	15	1000	0.784390	15274
12	15	1000	0.775283	15347
13	15	1000	0.734395	15286
14	15	1000	0.809528	15285
15	15	1000	0.790738	15276

Table 3 Comparisson of Computational Efficiency of Pso and Ga

Iterations	10	20	30	40	50
Generation Cost (Rs. /hr.) for PSO	15290	15283	15269	15261	15261
CPU Time (Sec.) for PSO	0.5551	1.2946	1.4820	1.7214	2.3667
CPU Time/ iteration (Sec.) for PSO	0.09	0.09	0.09	0.09	0.09
Generation Cost (Rs./hr) for GA	15620	15615	15608	15608	15605
CPU Time (Sec.)for GA	4.34	10.49	21.31	31.53	42.07
CPU Time/ iteration (Sec.)for GA	0.22	0.22	0.22	0.22	0.22

The relation between nos. of iterations and cost in Rs./hr for swarm size 1 is shown in Fig. 1. Cost is plotted on y-axis and nos. of iterations is plotted on x-axis. The relation between nos. of iterations and cost in Rs./hr for swarm size 2 is shown in Fig. 2. The relation between nos. of iterations and cost in Rs./hr for swarm size 3 is shown in Fig. 3. The relation between nos. of iterations and cost in Rs./hr for swarm size 4 is shown in Fig. 4. The relation between nos. of iterations and cost in Rs./hr for swarm size 5 is shown in Fig. 5. The graphical relation of Fig. 1 to Fig. 5 shows that the cost decreases with increase in nos. of iterations. The dimensional view of the particles converging to the best solution point in the search spaceis shown in Fig. 6.

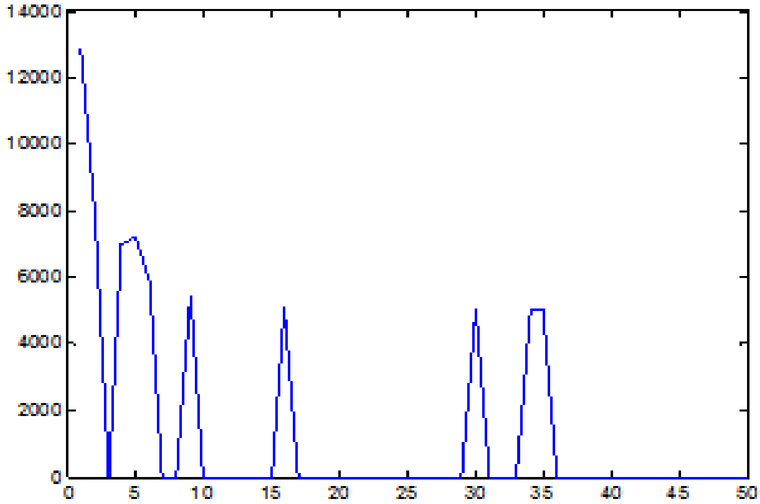

Fig. 1 Relation between 50 iteration and cost in Rs. / hr (swarm size = 1)

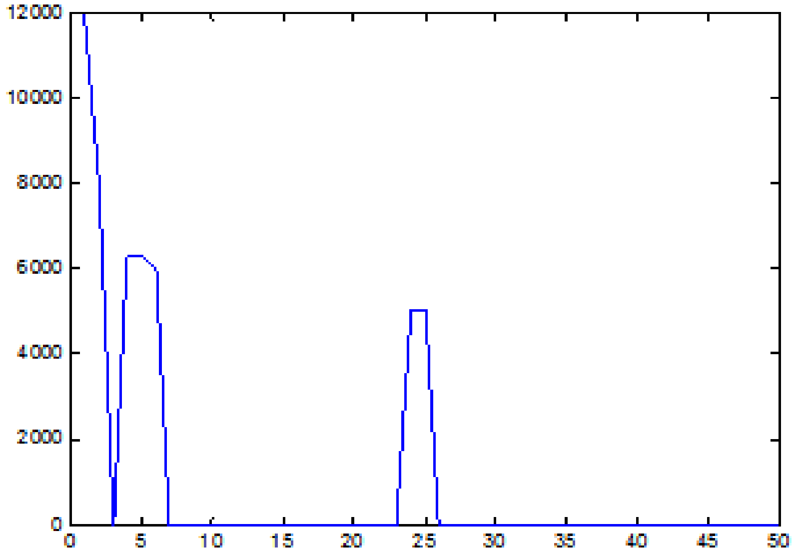

Fig.2 Relation between 50 iteration and cost in Rs. / hr (swarm size = 2)

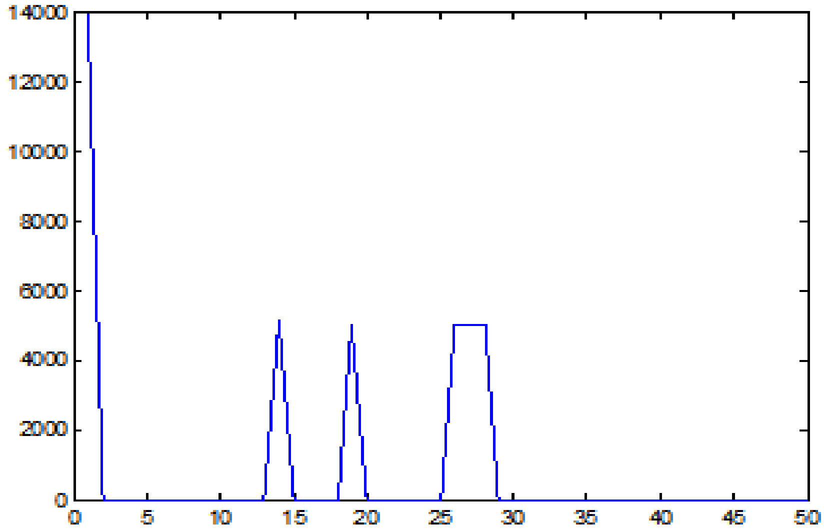

Fig.3 Relation between 50 iteration and cost in Rs. / hr (swarm size = 3)

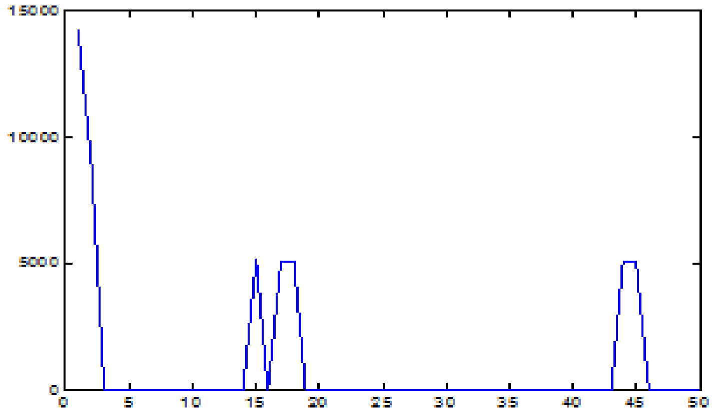

Fig.4 Relation between 50 iteration and cost in Rs. / hr (swarm size = 4)

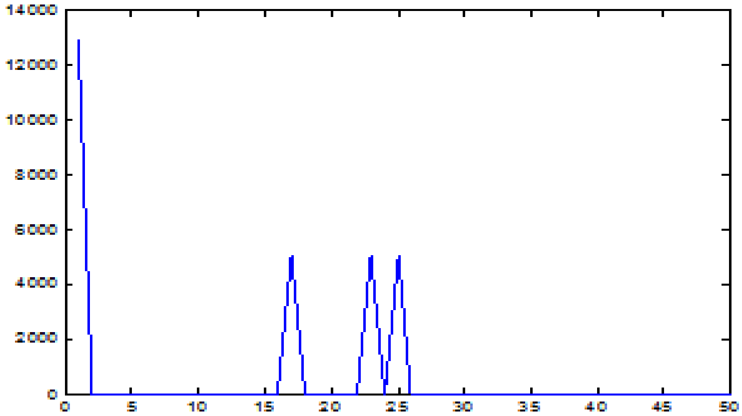

Fig.5 Relation between 50 iteration and cost in Rs. / hr (swarm size = 5)

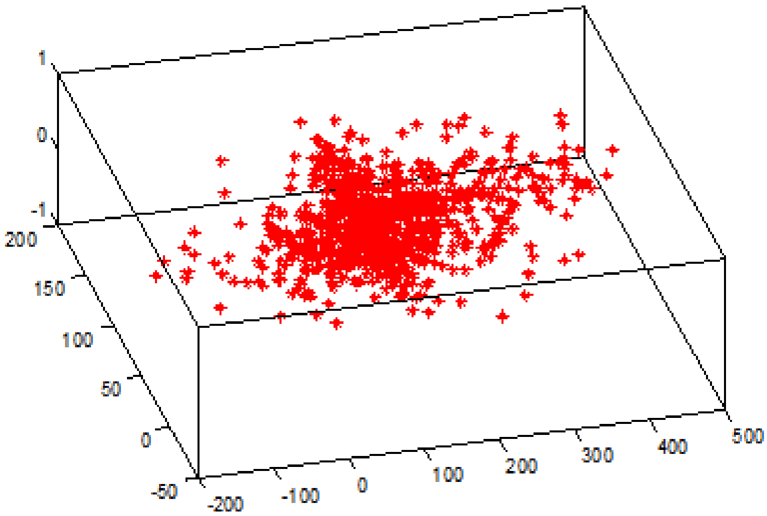

Fig.6 Dimensional view of the particles converging to the best solution point in the search space

V. CONCLUSION

The economic load dispatch is the optimization problem which is solved using PSO technique in the proposed study with less computational time and number of reasonable iterations The PSO algorithm is implemented using Matlab software with high speed. The Particle Swarm Optimization (PSO) technique gives the$gbest$value with less computational time. In the proposed study the PSO algorithm is also used for multi-dimensional, non-linear and non-differential problems. The computational time and generation cost in Rs./hr are less while using PSO as compared to the GA. The computational time is also less for PSO as compared to the GA. The simulations results prove the effectiveness of the PSO algorithm.

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BIOGRAPHIES

Ravinder Singh Maan

was born in Bhathinda inPunjab State of India on March19, 1991. He studied at Poornima Institute of Engineering & Technology, Jaipur and received the Electrical Engineering Degree from Rajasthan Technical University Kota,Rajasthan,India in 2011. He is currently Pursuing M.Tech (Power System) from Jagannath University Jaipur, India.

He has been Assistant Professor withJaipur National University, Jaipur, India since 2011. His special fields of interest are Application of AI Techniques in Power System and Power Electronics Devices.

Om Prakash Mahela

was born in Sabalpura (Kuchaman City) in the Rajasthan state of India on April 11, 1977. He studied at Govt. College of Engineering and Technology (CTAE), Udaipur, and received the electrical engineering degree from Maharana Pratap University of Agriculture and Technology (MPUAT), Udaipur, India in 2002. He is currently pursuing M.Tech. (Power System) from Jagannath University, Jaipur, India.

From 2002 to 2004, he was Assistant Professor with the RIET, Jaipur. Since 2004, he has been Junior Engineer-I with the Rajasthan Rajya Vidhyut Prasaran Nigam Ltd., Jaipur, India. His special fields of interest are Transmission and Distribution (T&D) grid operations, Power Electronics in Power System, Power Quality, Load Forecasting and Integration of Renewable Energy with Electric Transmission and Distribution Grid, Applications of AI Techniques in power system. He is an author of 23 International Journals and Conference papers. He is a Graduate Student Member of IEEE. He is member of IEEE Communications Society. He is Member of IEEE Power & Energy Society. He is Fellow Member of IAEME. He is Reviewer of TJPRC International Journal of Electrical and Electronics Engineering Research. Mr. Mahela is recipient of University Rank certificate from MPUAT, Udaipur, India, in 2002.

Mukesh Kumar Gupta

completed his B.E. Degree in Electronic Instrumentation & Control Engineering Branch in 1995 and M.E. Degree in Power System in 2009 from Engineering College Kota (RTU Kota) Rajasthan, India and he is pursuing Ph.D on Solar Energy from Jagannath University Jaipur, Rajasthan, India.