ISSN No.: 2454- 2024 (online)

International Journal of Technical Research & Science

A Hybrid Particle Swarm Optimization Gravitational Search Algorithm Technique applied on Economic Load Dispatch Problem

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Abstract-This research paper proposes a hybrid global - local algorithm –Hybrid Particle Swarm Optimization (HPSO) used to solve Economic Load Dispatch (ELD) Problem. The HPSO algorithm combines the classical Particle Swarm Optimization (PSO) with Gravitational Local Search Algorithm (GLSA) non -linear optimization method, present in the optimization implement in MATLAB commercial software product. The global optimizer is the PSO algorithm and a local one is GSA. The main objective is to minimize the non-linear objective function, which is the total fuel cost of thermal generating units having equality and inequality constraints. The proposed method hybrid PSO-GSA has been developed, evaluated for three thermal generating units and compared with several recently developed conventional and intelligence heuristic methods. For simulation result it has been found that the hybrid PSO-GSA is highly competitive and efficient due to its convergence characteristics.

Keywords— Economic Load Dispatch, Particle Swarm optimization, Gravitational Search Algorithm, Thermal Generating units

1. INTRODUCTION

Economic Load Dispatch (ELD) is a basic optimizing problem in power system planning, operating and controlling . Generally, there are of two types of ED problems which are Static and Dynamic problem. Solving Static ED problem is subject to the generator operating limits and power balance constraints .The dynamic ED problem takes the ramp rate limits of the generating units. The objective of ED is to evaluate the output power of all the thermal generating units of a given system so as to have reduce fuel cost on overall system In other words we can say that to minimize the non –linear objective function with equality and inequality operating limits. In the basic form of the mathematic model of the ED, the equality constraint is formulated by a single relation of the overall system's power balance, and the inequality constraint refer to keep the power of the generating units in its operating limits. The total fuel cost is the sum of all fuel costs of each generating unit. Conventionally the fuel cost for each generator is defined by a single quadratic function with or without the valve-point effects.

The methods for solving this kind of problem, which evaluates the total generating cost of all the units which supplying a load are conventional search methods and modern heuristics. Some of these algorithms fails due to their convergence characteristics so they don't give optimal solutions . Some modern algorithms successively give the global optimal solutions due to their rate of convergence .These global optimization methods are known as Direct Search Method. Conventional methods are like Linear Programming, Mixed–Integer Programming ,Newton Flow Programming and Intelligence methods such as Neural Network, Tabu Search, Particle Swarm Optimization, Fuzzy Set Applications are used to solve Economic Load Dispatch Problems. Many of these methods are stimulated by Swarm behaviour in nature.

The Gravitational Search Method is a new heuristic optimization method which is based upon Mass Interaction and Law of Gravity. This technique has a good ability to search the optimal solution but this suffers the slow searching speed in the last iterations. The objective is to evaluate the global best result among all the possible inputs. Two important characteristics are needed for global best solutions exploration and exploitation. This enforces the ability of algorithm to search every parts of the problem space whereas exploitation is the skill to give best optimal solution. So , there is a new hybrid particle swarm optimization model established combines the Particle Swarm Optimization(PSO) and Gravitational Search Algorithm (GSA) named as PSO-GSA. In this paper HPSO method is demonstrated and evaluated for three thermal generating units and some standard test functions are used to compare the hybrid algorithm with some other latest techniques .

2. ED PROBLEM FORMULATION

We consider Power system containing or Economic Load Dispatch (ELD) model consists of n generating units online, each units having its own generated power $P_{j,}$, here j=1,2,3…n, Fj represents the fuel cost of the j^{th}unit The total fuel cost is the summation of the costs of single individual units.

Mathematically, the complication may be expressed as to reduce the goal function, F_T which is equal to the amount of the individual cost of various generating units.

$$F_T = F_1 + F_2 + F_3 + \text{- - - - - - - -} + F_N \tag{2.1}$$

$$\min f = \sum_{t=1}^{T} \sum_{j=1}^{N} F(P_j(t)) \qquad 2.2$$

Depending on constraint that amount of power generated must be equal to load demand.

$$\sum_{j=1}^{N} P_j(t) = P_D(t) + P_L(t) \qquad 2.3$$

$$P_{j\,\min} \leq P_j(t) \leq P_{j\,\max} \qquad 2.4$$

Where t is the interval number, n is the full amount numbers of stanch units, P_j (t) is an output active power of j unit ata time t, P_{jmin} is the minimum yield of the unit j, $P_{jmax}$is maximum productivity of the unit j, P_D (t) is load insist at a time interval t, P_L (t) is the network loss at a time interval t.
The ED problem can be expressed as

2.1 Fuel Cost Model

$C(P_{Gi})=\Sigma(a_i*P_{Gi}^2+ b_i*P_{Gi} +c_i)$Rs where i=1…..N(a,b,c are cost coefficients)

2.2 Power Balance Constraints:

$\Sigma P_{Gi}-P_D-P_L=0$(Power Generation=Power Demand+ Power Losses)
$P_{Gi,min}\leq P_{Gi}\leq P_{Gi,max}$ where i=1,2……N
(Power Generation Limits)

2.3 Total Operating Cost Minimization:

Total Operating Cost=C

In the methodology of constant loss formula coefficients (loss coefficient method) or B-coefficients, the network losses are expressed as a quadratic function of the generators power outputs that can be approximated in the form:

$$P_L=\Sigma_i^n \Sigma_j^n B_{ij}P_iP_j + \Sigma_i^n B_{i0}P_i + B_{00}$$

Where B_{ij} are the elements of loss coefficient square matrix B, B_{i0} is the ith elements of the loss coefficient vector and B_{00} is the loss coefficient constant.

The swarm optimization algorithms were applied to minimize the following objective function:

$$f= \Sigma_i^n F_i(P_i) + q_1(abs(\Sigma_i^n P_i-P_l-P_d))$$

Where q_1 is a positive constant to penalize the solutions that does not attend the power load balance.

3. SOLUTION OF ED PROBLEM WITH GLSPSA

The plan for the hybridization of gravity inspired particle swarm optimization is to combine the strength of the collective thinking factor of particle swarm optimization with the restricted search power of gravity based local search algorithm.
This technique accepts the agents as objects and the position of ith agent is expressed by:-
$X_i = (x_i^1…… x_i^g………… xi^n)$ where i=1……N
Where x_i^g is the location in the g^{th} dimension of the i^{th} agent. and the masses are obtainable randomly.

3.1 Evaluation Of Force

The force acting on mass i^{th} from the mass j^{th} is expressed as

$$F_{ij}^d= G(t) * (M_i(t)*M_j(t))/R_{ij}+\Omega * (X_j^d(t)- X_i^d(t))$$

Where G(t) is the gravitational constant at a time t, $R_{ij}(t)$ is distance between i and j objects ,$M_i(t)$ and $M_j(t)$ are the masses of the agents j^{th} and i^{th} at a time t , Ω is a small constant and represented as the given below:

$$R_{ij}(t) = ||X_i(t),X_j(t)||_2$$

Gravitational constant G (t) is started in the arbitrary fashion in the beginning and is decremented over the period time to systematize and results the exploration precision.

$$G(t)=G_0\, e^{\alpha t/T}$$

Where G_0 is the original value of gravitational constant, T is the maximum number of the iterations ,α is the user invariable and t is the existing iteration. G is gravitational constant which is the function of time “t” and the initial value G_0 .

ISSN No.: 2454- 2024 (online)

International Journal of Technical Research & Science

Supposed the total force acting on agent i in the dimension d is obtainable as :- $F_i^d(t) = \Sigma_{j=1, j\neq 1}^{N} rand_i\, F_{ij}^d(t)$

Where F_{it} is the force acting on agent i[th] at t iteration and randi is a random number between the interval [0, 1].

3.2 Evaluation Of Acceleration

The acceleration of i^{th} agent at iteration t having d dimension is according to the law of motion

$$\alpha c_i^d(t)=F_i^d(t)/M_i(t)$$

3.3 Evaluation Of Velocity

The velocity of an agent is expressed as:-

$$V_i^d(t+1)=w.v_i^d(t)cj \text{ x } rand \text{ x } c_i^d(t)+c_2 \text{ x } rand \text{ x } (gbest-x_i^d(t))$$

Where cj is a weighting factor, w is a weighting function, rand is a random number between 0 and 1, $v_i^d(t)$ is the velocity of the agent i^{th} at iteration t in dimension d, αc_i^d (t) is the acceleration of i^{th} agent at the iteration t in dimension d^{th} and gbest is the best solution found .

At every , iteration the location of an agent is given as:-

$$X_i^d(t+1)= x_i^d(t) +v_i^d(t+1)$$

Where v_i^d (t+1) is the velocity of next agent and x_i^d is the position of ith agent in dth dimension at iteration t.

3.4 Evaluation Of Mass

The value of masses of agents are expressed by the comparison of fitness:-

$$m_i(t)=currentfitness_i(t)- 0.99*worst(t)/(best(t)-worst(t)$$

$$M_i(t)=m_i(t)*5/\Sigma_{j=1}^{n} m_j(t)$$

Where the current-fitnessi is the fitness value of the agent i at any time t and best (t) and worst (t) are the least and the highest fitness value of all the agents. The agents browsing in the search space which are taken towards the other agents by means of the gravity of force and pushes a run to the agents which are having the heavier mass. The heavier mass expresses a good solution. Here the *gbest* assists them in calculating the global optimal result. The optimal solution gets by using the exploitation ability of particle swarm optimization.

4. Implementation of PSOGSA algorithm for economic load dispatch

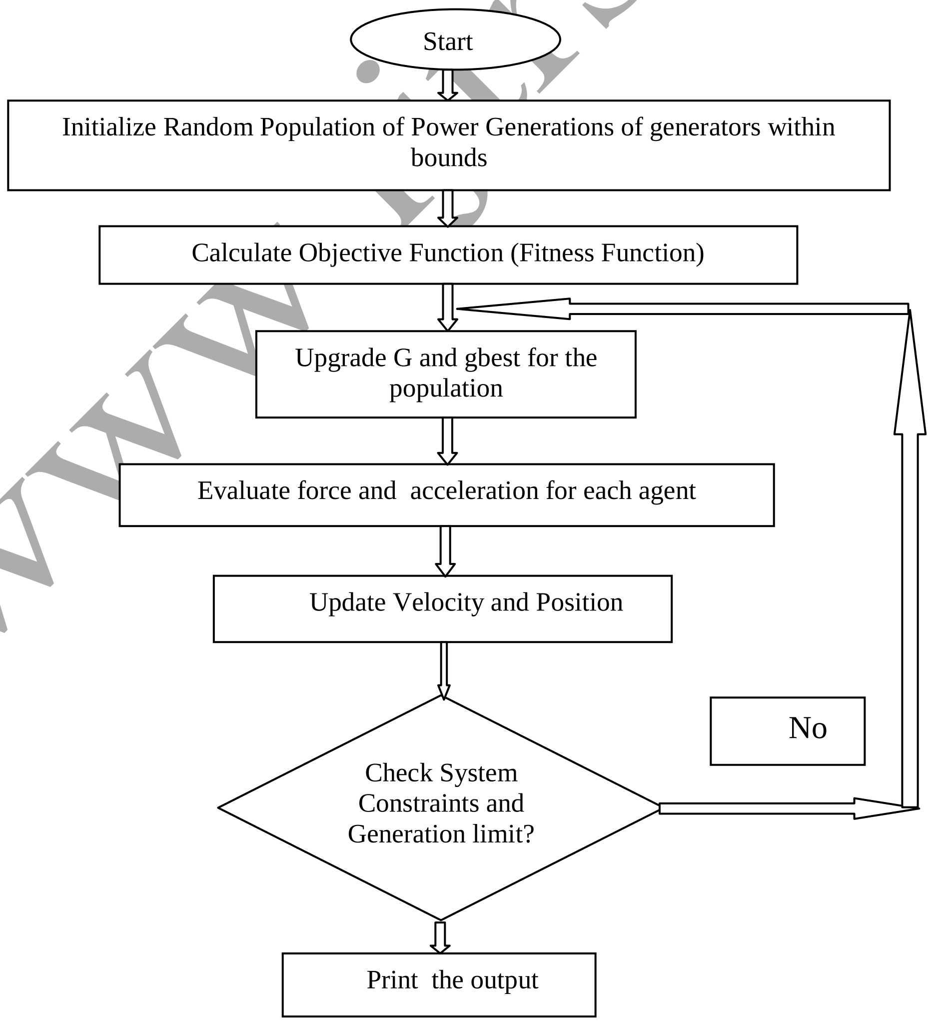

Fig. 4.1 Flow chart of PSOGSA

4.1 Simluation Flow

Step1: Feasible Boundary Position

Agents i^{th} and j^{th} are initialized and power generation must be located between minimum and maximum operating limits of the generators. Each agent should be satisfy with the system constraints.

Step 2: Objective Function

This evaluates fitness for each agent while constraints are satisfied. Update G and Gbest for the population.

Step 3: Force Evaluation

Total force acting on agent i in different dimensions is evaluated.

Step 4: Evaluation of Acceleration and Mass of an Agent

The acceleration of ith agent in d dimension is solved and mass is calculated.

Step 5: Update Position and Velocity of Every Agent

The next velocity of agent is calculated and position is updated.

Step 6: Finishing Criteria

Repeat process 2 to 5 until maximum number of iterations is reached.

5. EXPERIMENTS

5.1 Data of three thermal generating units

The case study incorporates three thermal generating units. The coefficients of fuel cost a , b and c of respective thermal units 1 ,2 and 3 and the minimum and maximum limits of power the individual generating units in (MW) while satisfying the equality and inequality constraints imposed to the system are shown in table . In this case the load demand predictable (Pd) to be determined as 150MW.

Table-5.1 Detail data of three thermal units

Unit	a($/MW^2)	b($/MW)	c($)	PG^{min}(MW)	PG^{max}(MW)
1	0.008	7	200	10	85
2	0.009	6.3	180	10	80
3	0.007	6.8	140	10	70

Table-5.2 Detail data of six thermal generating units

Unit	a($/MW^2)	b($/MW)	c($)	P^{min}(MW)	P^{max}(MW)
1	0.007	7	240	100	500
2	0.005	10	200	50	200
3	0.009	8.5	220	80	300
4	0.009	11	200	50	150
5	0.0080	10.5	220	50	200
6	0.0075	12	120	50	120

5.2 Experiment Results

The results of hybrid PSO (PSOGSA) technique are obtained by the implementation being done in MATLAB for data has been taken of respective thermal units.

Table 5.3 Results of best Simulation with three thermal generating units

Power Output	GLSPSA	CS	ABC	FA	GSA
UNIT1 (MW)	45.5201	33.490	33.049	32.729	34.51
UNIT2 (MW)	55.7065	64.116	61.764	63.843	62.74
UNIT3 (MW)	50.7734	55.126	57.872	56.151	58.92
P_L(MW)	2	2.73	2.69	2.72	2.73
P_D(MW)	150	150	150	150	150
ΣP_i(MW)	152	152.73	152.69	152.72	152.73
Cost ($/hr)	1541.1	1600.46	1600.51	1600.47	1600.56

Table-5.4 shows best simulation results with six thermal generating units

Power Outputs	PSOGSA	CS	FA	ABC
UNIT 1 (MW)	291.5352	324.113	293.312	323.043
UNIT2 (MW)	110.1770	76.859	79.546	54.965
UNIT3 (MW)	156.9245	158.094	123.334	147.354
UNIT4 (MW)	52.3801	50.000	69.700	50.000
UNIT5 (MW)	50.000	51.963	79.546	85.815
UNIT6 (MW)	50.0000	50.000	63.778	50.233
P_l (MW)	11	11.03	11.44	11.40
P_d (MW)	700	700	700	700
ΣPi (MW)	711	711.03	709.22	711.40
Cost ($)	8338.00	8356.06	8388.45	8372.27

In this paper the results of three thermal units are shown along with simulation results that will explain the convergence characteristics. The results obtained are compared with GSA (Global search algorithm), FA (firefly algorithm), ABC (artificial bee colony), and CS (cuckoo search).

5.3 Simulation Results

There are Simulation result, explains the rate of convergence of thermal units. This Fig. concluded that this algorithm takes less no. of iteration hence takes less computational time to give best fuel cost.

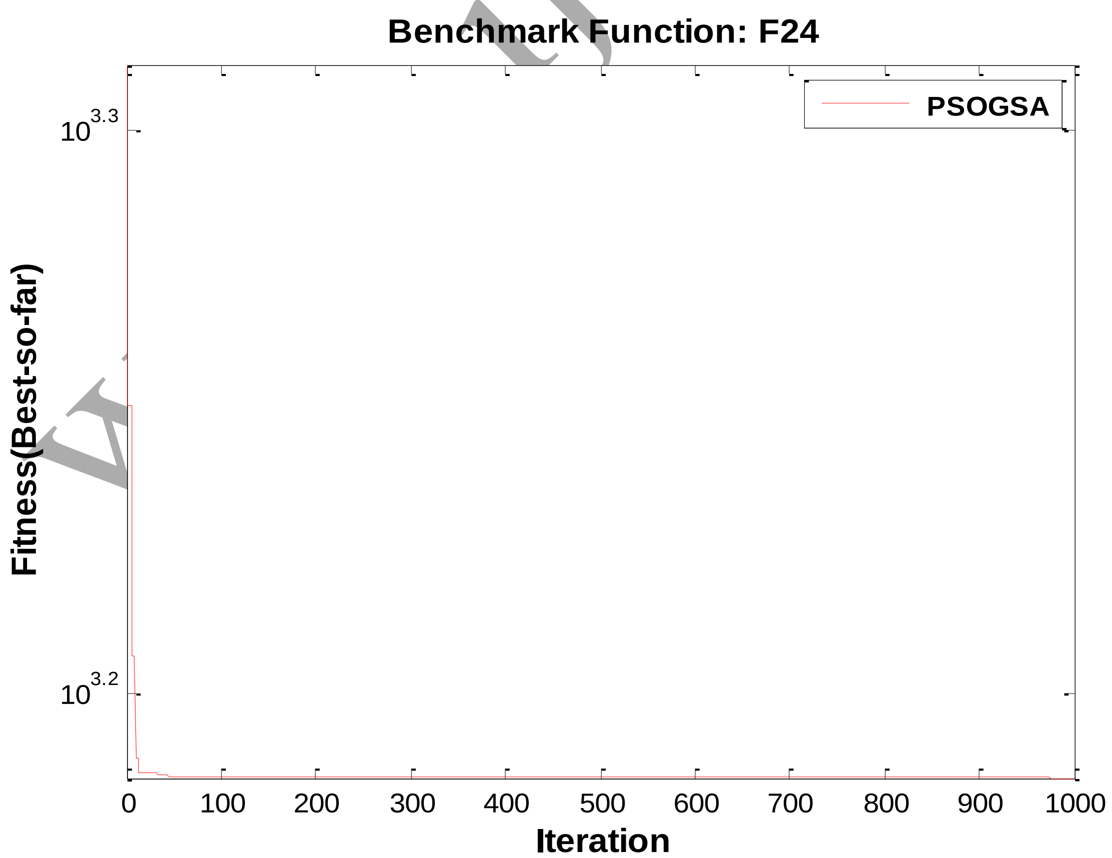

Fig. 5.1 Convergence characteristics of PSOGSA with load demand 150 MW

ISSN No.: 2454- 2024 (online)

International Journal of Technical Research & Science

CONCLUSION

A new approach to the solution of ED using particle swarm optimization with gravitational search algorithm has been proposed, the solution time as well as the quality is greatly improved. Hybrid PSO (GLSPSA) method was successfully employed to solve the ELD problem. The generation limits and demand is considered for practical use in the proposed method. The comparison of results fuel cost of three generating units shows that the PSOGSA method was indeed capable of obtaining high quality solution efficiently for ELD problems.
PSOGSA is thus an effective method in solving economic load dispatch problem since it works with progressive improvement. The convergence to a global point leads to cost savings and hence profits maximization. The algorithm thus, is relatively simple, reliable and efficient hence suitable for practical applications.

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