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Relevance of Particle Swarm Optimization Technique for the Solution of Economic Load Dispatch Problem

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Abstract- *Economic Load Dispatch is very vital research in generation of electrical power system. It is method by which we can make a plan of the preeminent achievable output of a number of generators power units so that to meet the domestic, industrial agriculture load demand at minimum possible cost, while satisfy all transmissions loss and operational constraints. This research paper tries to present the relevance of particle swarm optimization technique for the mathematical formulation of Economic load dispatch problem using soft computing technique in power generation system considering various parameters like load demand, physical and generation system constraints.*

Index Terms- **Economic Load Dispatch problem (ELDP), relevance Particle Swarm Optimization, Basic mathematical formulation,.**

I. INTRODUCTION

In electrical power system, seven types of generation system mostly are used in world like thermal, hydro, nuclear, bio-mass, tidal wave, solar and wind energy etc. Consumer load demand it may be (industrial, agriculture, domestic etc.) change according to load parameters and reaches the different maximum values. so, it is very essential to scheduling of power generating units by which units can turn off and on to meet the desire power load demand and also keeping in mind cost parameter order in which the units must be shut down. The entire effort of draw round and manufacture these evaluations are known as economic load dispatch. It means that generation unit output (Min. MW to Max. MW) are permissible to diverge within certain confines so that to meet a particular load demand obtained by minimum fuel cost.

II. ECONOMIC LOAD DISPATCH

Economic Load Dispatch problem is very important in electric power generation plant units. The main objective of the Economic Load Dispatch problems is to create the best probable schedule of power generators outputs of all units so as to bring together the required load demand at minimum operating cost while satisfying the equality and inequality constraints.[1] The cost function for each generators unit in Load Dispatch problems has been around defined by a quadratic function in which fuel cost, power load demand, equality and inequality constrained are involved.

III. PROBLEM FORMULATION

The economic dispatch problem is a constrained optimization problem and it can be expressed as
Follows.[1-4]
Minimize

$$F(P_i) = \sum_{i=1}^{NG} (a_i P_i^2 + b_i P_i + c_i) \qquad Rs/h \qquad (1)$$

Where, a_i (Rs/MW^{2}h), b_i (Rs/MWh) and c_i (Rs/h) are fuel cost coefficients of ith unit.

Subject to (i) the energy balance equation

$$\sum_{i=1}^{NG} P_i = P_D + P_L \qquad (2)$$

(ii) The inequality constraints

$$P_i^{\min} \le P_i \le P_i^{\max} \qquad (\text{i} = 1, 2, 3, \ldots\ldots\ldots\ldots, \text{NG}) \qquad (3)$$

Where, a_i, b_i and c_i are cost coefficients
P_L is power transmission Loss.
NG is the number of generation units
P_D is Load Demand.
P_i is real power generation and will act as decision variable.

The very simple and fairly accurate method of expressing power transmission loss, P_L as a function of generator powers is through George's Formula using B-coefficients and mathematically can be expressed as:

$$P_L = \sum_{i=1}^{NG} \sum_{j=1}^{NG} P_{g_i} B_{ij} P_{g_j} \quad \text{MW} \qquad (4)$$

where, P_{g_i} and P_{g_j} are the real power generations at the i^{th} and j^{th} buses, respectively. B_{ij} are the loss coefficients which are constant under certain assumed conditions.

IV. THERMAL CONSTRAINTS

In this system thermal generation unit needs to undergo gradual temperature vary and thus it takes some period of time to carry a thermal generation unit online. Also, thermal unit can be manually controlled. So a crew member is required to perform this task in operation.. This leads to a lot of limitations in the power system operation of thermal unit and thus it provide rise to many constraints.

V. GENERATION CONSTRAINTS

In order to convince the forecasted in power system load demand, the sum of all generating units on-line must equal the power system load over the time horizon.

$$\sum_{i=1}^{NG} P_{ih} U_{ih} = D_h \qquad (5)$$

Where, D_h is load demand at h^{th} hour.
P_{ih} is the power output of ith unit at hth hour
U_{ih} is the On/Off status of the ith unit at the hth hour.
NG is the number of thermal generating units

VI. UNIT GENERATION RESTRICTIONS

The power output induced by the individual units must be within max. and min. generation limits i.e.

$$P_{i(\min)} \le P_{ih} \le P_{i(\max)} \qquad (6)$$

Where, $P_{i(\min)}$ and $P_{i(\max)}$ is the minimum and maximum power output of the i^{th} unit.

VII. PARTICLE SWARM OPTIMIZATION

Particle Swarm Optimization (PSO) is a soft computing technique. It is swarm-based intelligence algorithm predisposed by the group behaviour of animals such as a flock of birds finding a food source which likely fly in sky or a school of fish protecting them from a difficulty or predator. This soft computing technique particle swarm optimization first described by james Kennedy and Russell C. Eberhart in 1995 draw from two separate conce pts ,the idea of swarm intelligence based off the surveillance of swarming habits by certain kinds of animal s(such as fish & birds) and field of evolutionary computation.

VIII. MATHEMATICS INVOLVED IN PSO

This algorithm works by discretely maintaining a no. of runner solutions in the search space. for the (P_{ih}) is period of all iteration of the algorithm, every candidate solution is calculated by objective function being optimized, determining fitness of that solution. Every runner solution can be thought of as particle 'flying' all the way through fitness landscape finding the max. or min. of the objective function. In beginning, particle swarm optimization algorithm select candidate solutions randomly within the search space.

V_i^{new} □ $w * V_{ij}$ □ $C_1 R_1$ □Pb^{best}_{ij} □ P_{ij} □□□ $C_2 R_2$ □G^{best}_J □ P_{ij} □□□i □ 1, 2...NP;j □1, 2...NG□ □□□□□□

P^{i}_{new} □ P_j □$_V$ new (8)

C_1 , C_2 are the acceleration constants
P is current position of j^{th} member of i^{th} particle at u^{th} iteration

NG is the no of members in a particle R_1, R_2 is random number between 0 and 1 and W is the weighing function or inertia weight factor NP is the number of particles in a group.

In figure 1. Flow chart shows the initial parameter of state of PSO constant, C1, C2 particle (P)and dimension (D) seeking the global maximum in a one-dimensional search space. The investigate space is composed of all the possible solutions along with the objective function. We know that the particle swarm optimization algorithm has no in sequence of the necessary objective function, and thus has no idea of knowing if someone of the candidate solutions are distance or far from a local or global max.

IMPLEMENTATION OF CLASSICAL PSO FOR ELD SOLUTION

The main objective of ELD is to obtain the amount of real power to be generated output by each committed generator, while achieving a minimum generation cost within the constraints. The details of the implementation of PSO components are summarized in the following subsections.
The search procedure for calculating the optimal generation output of each unit is summarized as follows:

1. Initialization of the swarm: For a population size P, the particles are randomly generated in the range 0-1 and Searched between the maximum and the minimum operating limits of the generators. If there are N generating units, the ith particle is represented as

$$Pi = (Pi1, Pi2, Pi3 \ldots\ldots PiN) \quad (9)$$

The jth dimension of the ith particle is allocated a value of Pij as given below to satisfy the constraints.

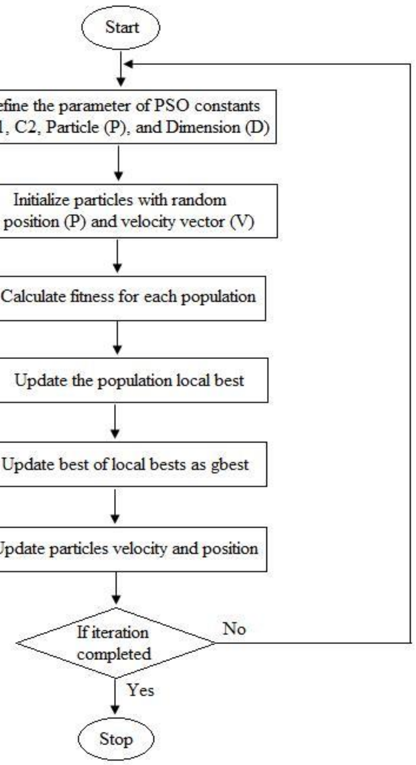
$$Pij = Pjmin + r\,(Pjmax - Pjmin) \quad (10)$$

Here r [0,1]

2. Defining the evaluation function: The merit of each individual particle in the swarm is found using a fitness function called evaluation function. The popular penalty function method employs functions to reduce the fitness of the particle in proportion to the magnitude of the equality constraint violation. The evaluation function is defined to minimize the non-smooth cost function given by equation The evaluation function is given as Min f(x)=f(x)+ lambda (equality constraints).

3. Initialization of P-best and G-best: The fitness values obtained above for the initial particles of the swarm are set as the initial Pbest values of the particle. The best value among all the Pbest values is identified as G-Best .

4. Evaluation of velocity: The update in velocity as per flow chart.



5. Check the velocity constraints of the members of each individual from the following conditions

If, Vid (k+1) > Vd max, then Vid (k+1) = vd max, (11)

Vid (k+1) < Vd min

then, Vid (k+1)=vd min
Where, Vdmin = -0.5 Pgmin, Vdmax = +0.5 Pg max

6. Modify the member position of each individual Pg according to the equation

$$Pgid\,(k+1) = Pgid\,(i) + Vid\,(k+1) \quad (12)$$

Pgid (k+1) must satisfy the constraints, namely the generating limits. If Pgid (k+1) violates the constraints, then Pgid (k+1) must be modified towards the nearest margin of the feasible solution.

7. If the evaluation value of each individual is better than previous P-best, the current value is set to be P-best. If the best P-best is better than G-best, the best P-best is set to be G-best. The corresponding value of fitness function is saved.

8. If the number of iterations reaches the maximum, then go to step 10. Otherwise, go to step-2

IX. TEST SYSTEM , RESULT AND DISCUSSION

In order to show the effectiveness of the Proposed PSO Algorithm for Short-term Unit Commitment Problem, three different types of test systems have been taken into consideration:

- The first test system consists of 5-Generating units has been taken from IEEE 14-Bus System with a time varying load demand for one day.
- The second test system consists of 6-Generating units has been taken from IEEE 30-Bus System with a time varying load demand for one day.
- Proposed PSO result Compare the result of firefly algorithm

Test System-I

Table-I: Generator characteristics of 5-Unit Test System

UNITS	P_{max}	P_{min}	A	B	C
Unit1	250	10	0.00315	2	0
Unit2	140	20	0.0175	1.75	0
Unit3	100	15	0.0625	1	0
Unit4	120	10	0.00834	3.25	0
Unit5	45	10	0.025	3	0

Table-II: Time varying load demand and result of 5 units

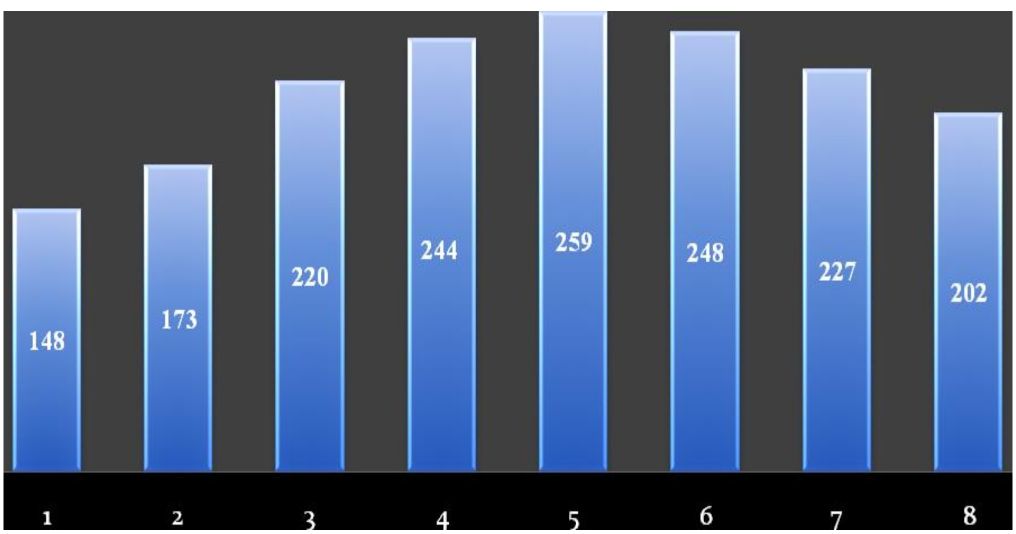


Table III. Optimal output of 5 units system which show the load demand fulfill with min. cost

Load Demand (MW)	No. of Iteration	U1	U2	U3	U4	U5	Min Cost Rs./h.
148	30000	86.9737	26.0257	15.0000	10.0000	10.0000	21276.6
173	30000	107.8218	30.1765	15.0000	10.0000	10.0000	25878.8
220	30000	145.0667	38.2486	16.7040	10.0000	10.0000	33696.5

244	30000	163.9007	42.2674	17.8340	10.0000	10.0000	38238.6
259	30000	175.7110	43.7893	18.5164	10.0000	10.0000	41198.0
248	30000	167.1512	42.9141	17.9329	10.0000	10.0000	39036.4
227	30000	130.5524	35.4128	15.0340	10.0000	10.0000	34985.6
202	30000	131.0699	35.2017	15.8565	10.0000	10.0000	30442.2

Test System-II

Table-IV: Generator characteristics of 6-Unit Test System

UNITS	P_{max}	P_{min}	A	B	C
Unit1	200	50	0.00375	2	0
Unit2	80	20	0.0175	1.7	0
Unit3	50	15	0.0625	1	0
Unit4	35	10	0.00834	3.25	0
Unit5	30	10	0.025	3	0
Unit6	40	12	0.025	3	0

Table-V: Time varying load demand and result of 6 units

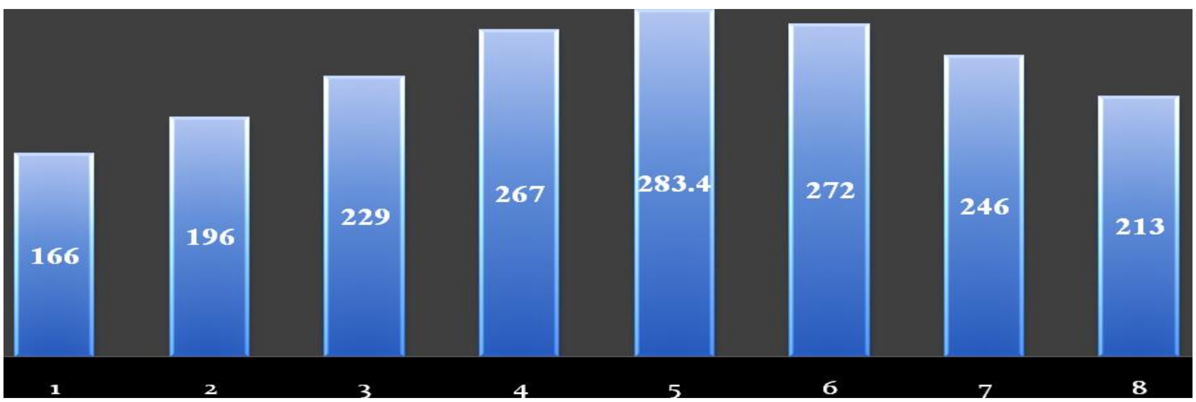


Table VI. Optimal output of 6 units system which show the load demand fulfill with min. cost

Load Demand (MW)	No. of Iterations	U1	U2	U3	U4	U5	U6	Min Cost Rs/h
166	30000	91.3180	27.6778	15.0000	10.0000	10.0000	12.0000	24561.6
196	30000	115.7033	33.2949	15.0000	10.0000	10.0000	12.0000	29516.6
229	30000	141.5913	38.9124	16.4955	10.0000	10.0000	12.0000	35383.1
267	30000	171.4119	45.3026	18.2847	10.0000	10.0000	12.0000	42651.5
283.4	30000	183.9935	48.1629	19.2428	10.0000	10.0000	12.0000	45965.8
272	30000	175.3349	46.1432	18.5211	10.0000	10.0000	12.0000	43632.6
246	30000	155.0839	41.6795	17.2346	10.0000	10.0000	12.0000	38571.8
213	30000	129.0093	36.2425	15.7474	10.0000	10.0000	12.0000	32587.6

COMPARISION OF RESULT

Table VII. Cost coefficients and power limits of 3-Unit system

Unit	A	B	C	Pmin.	Pmax.
1	756.79886	38.53	0.15240	10	125
2	451.32513	46.15916	0.10587	10	150
3	1049.9977	40.39655	0.02803	35	225

Table VIII Comparison of test results of firefly and particle swarm optimization method.

S.No.	Power Demand(MW)	Fuel Cost (Rs/hr) Lambda iteration method	Fuel Cost (Rs/hr) Firefly Algorithm	Fuel Cost (Rs/hr) Particle Swarm Optimization
1	350	18570.7	18564.5	18320.80
2	400	20817.4	20812.3	20469.83
3	450	23146.8	23112.4	22670.54
4	500	25495.2	25465.5	24909.77
5	550	27899.3	27872.4	27189.47
6	600	30359.3	30334.0	29506.31
7	650	32875.0	32851.0	31859.80
8	700	35446.3	35424.4	34252.73

Table IX. Cost coefficients and power limits of 6-Unit system

Unit	A	B	C	Pmin.	Pmax.
1	756.79886	38.53	0.15240	10	125
2	451.32513	46.15916	0.10587	10	150
3	1049.9977	40.39655	0.02803	35	225
4	1243.5311	38.30553	0.03546	35	210
5	1658.5696	36.32782	0.02111	130	325
6	1356.6592	38.27041	0.01799	125	315

Table X Comparison of test results firefly and particle swarm optimization method.

S.No.	Power Demand(MW)	Fuel Cost (Rs/hr) Lambda iteration method	Fuel Cost (Rs/hr) Firefly Algorithm	Fuel Cost (Rs/hr) Particle Swarm Optimization
1	600	32129.8	32094.7	31426.57
2	650	34531.7	34482.6	33680.10
3	700	36946.4	36912.2	35997.43
4	750	39422.1	39384.0	38291.39
5	800	41959.0	41896.9	40642.86
6	850	44508.1	44450.3	43019.66
7	900	47118.2	47045.3	45422.18
8	950	49747.4	49682.1	47835.37

The corresponding results has been obtained using Particle Swarm optimization Technique using Population Size=50 and Maximum Iteration=30000. The Flow chart for economic load dispatch Problem using PSO is shown in Figure-1. The MATLAB Simulation software 7.12.0 (R2010a) is used to obtain the corresponding results.

XI. CONCLUSION

In this research paper, researchers have done the relevance Particle Swarm Optimization Algorithm for solution of ELDP. The results for standard IEEE Bus system consisting of five and six Generating system units has been profitably evaluated using PSO. The following important points are observed throughout whole research works:

- By planned PSO algorithm, Fuel cost (FC) of 350 MW is 18564.5 and by firefly algorithm FC is 18320.80 for three unit system.
- Load demand 350 MW to700 MW is shown in table (viii)
- By planned PSO algorithm, Fuel cost (FC) of 600 MW is 31426.57 and by firefly algorithm FC is 32094.7 for six unit system.
- Load demand 600 MW to 950 MW is shown in table (x)
- Proposed algorithm has simple implementation, require less computational time and very few algorithm parameters.

XI. FUTURE SCOPE

(1) Particle Swarm Optimization Algorithm is based on the intellect. It can be applied into both scientific engineering work and research purpose.

(2 The search can be carried out by the speed of the particle .Particle Swarm Optimization Algorithm has no overlapping and mutation calculation.

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