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Research Article

ECONOMIC DISPATCH WITH VALVE POINT EFFECT USING MODIFIED VERSION OF PARTICLE SWARM OPTIMIZATION TECHNIQUES

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ABSTRACT

The modified versions of particle swarm optimizer have been applied to the economic power dispatch with valve point effects. The proposed algorithms were applied to thirteen generator data. In order to obtain the better resolution, speed of junction and time of execution. The comparison among the particle swarm optimization and other modified particle swarm optimization has been done to obtain the best and worst values for thirteen generator units. Numbers of iteration and total generation costs are represented graphically for all the modified PSO techniques. The research paper is mainly focused on the economic dispatch with valve point effect using modified version of particle swarm optimization techniques.

Keywords: Economic power dispatch, Valve point effect, Particle swarm optimization

INTRODUCTION

The main purpose of economic load dispatch is to minimize the total generation cost of the plant by considering the generator limits. In power generation fuel cost plays major role and the factors which influence power generation at minimum cost are operating efficiencies of fuel cost and transmission losses. Z. L. Gaing *et al.* explicated the power system optimization problems such as economic dispatch considering the generator constraints[1]. S. H. Ling et al. illustrated the global search techniques including genetic algorithm[2]. In the similar manner, Jiejing explained the chaotic particle swarm optimization for economic dispatch for considering the generator constraints[3]. B.K.Panigrahi represented the adaptive particle swarm optimization approach for static and dynamic economic load dispatch[4]. The research paper shows that the proposed approaches will be best resolution method than the other methods.

The main aim is to identify the generation of different plants, such that the total operating cost is minimum. The major component of generator operating cost is the fuel input/hour and the maintenance cost contributes very less. The optimization techniques used are PSO, CPSO and SAPSO, a random population is initialized and the fitness value of each is calculated. This population is sent through a selection process where the probability of the member of the population being selected into the matting population is directly proportional to the previously measured fitness. Velocity limits of the generators are initialized and it has been carried out by initializing the generating velocities, besides those iterations are started and best values are found out by continuously updating the population and also finding the fitness of the present population[5].

(i) ECONOMIC LOAD DISPATCH

Economic dispatch problem is to minimize the total cost of generating real power (production cost) at various stations, while satisfying the loads and losses in the transmission lines. In the load flow problems, two variables are specified at each bus and solutions is obtained for the variables.

In a practical power system, power plants are not loaded at the same distance from the center of loads and their fuel cost is different. The generation capacity is more than the demand and losses. So there is a need to schedule the generation.

Problem Formulation

The economic dispatch problem is formulated as,

$$Min\ FC_{total} = \sum_{i=1}^{N_G} FC_i \rightarrow (1)$$

Subjected to the constraint,

$$\sum_{i=1}^{N_G} P_i = P_D \rightarrow (2)$$

The generator operating cost is the factors which influence power generation at minimum cost is operating efficiencies of generator, fuel cost and transmission losses. Efficient generator in the system does not generate minimum cost as it may be located in an area, where fuel cost is high. If the plant is located far from the load centre, transmission losses may be higher and the plant may be uneconomical. The main aim is to identify the generation of different plants, such that the total operating cost is minimum. The major component of generator operating cost is the fuel input/hour and the maintenance cost contributes very less.

(ii) VALVE POINT EFFECT

When the load demand increases the speed of the generator will be decreased automatically. We know that; the generator is coupled with prime mover (turbine), so to increase the speed of the generator the valve point is connected in the turbine and then opened gradually, the turbine starts rotating faster hence generator gets back almost to the its original speed. The valve point effect is added in the economic load dispatch problem to increase the accuracy of the total fuel cost however the cost function of a generator is not always differentiable due to the valve-point effects and/or change of fuels. The valve-point effects introduce ripples in the heat-rate curve. The fuel cost function with valve-point loadings of the generators is usually modeled as,

$$FC_i = \sum_{i=1}^{N_G} a_i + b_i P_i + c_i P_i^{\,2} + \left| e_i \sin(f_i (P_{i(\min)} - P_i)) \right| \rightarrow (3)$$

Where a_i, b_i, c_i are fuel cost coefficients of generator [i].

e_i and f_i are fuel cost coefficients of generator [i] with valve point effect.

(iv) PARTICLE SWARM OPTIMIZATION

The particle swarm optimization is based on researches about swarms such as fish schooling and a flock of birds. It was originally developed for non-linear optimization problems with continuous variables. Conversely, it is easily expanded to treat problems with discrete variables. Consequently, it is applicable to both continuous and discrete variables.

The basic postulation behind the PSO algorithm is, birds find food by flocking and not individually. This leads to the assumption that information is owned jointly in flocking. This is modeled by particles in multi-dimensional space that have a position and a velocity. These particles are flying through hyperspace (i.e., Rn) and have two essential reasoning capabilities: their memory of their own best position and knowledge of the swarm's best. Members of the swarm communicate good positions to each other and adjust their own position and velocity based on these good positions. There are two main ways this communication is done:

- ✓ A "global best" that is known to all
- ✓ "Neighborhood" bests where each particle only communicates with a subset of the swarm about the best positions

An algorithm is presented below, where there is a global best rather than neighborhood bests. Neighborhood bests allow better exploration of the search space and reduce the susceptibility of pso to falling into local minima, but he slow down convergence speed. Note that neighborhoods merely slow down the proliferation of new best, rather than creating isolated sub swarms because of the overlapping of neighborhoods: to make neighborhoods of size 3, say, particle 1 would only communicate with particles 2 through 5, particle 2 with 3 through 6, and so on. But then a new best position discovered by particle 2`s neighborhood would be communicated to particle 1`s neighborhood at the next iteration of the PSO algorithm presented below. The smaller neighborhoods are faster convergence, with a global best representing a neighborhood consisting of the entire swarm. In the following sections we will deal with the main algorithms being used in the program.

(v) IMPLEMENTAION OF PSO, CPSO AND SAPSO METHODS IN ECONOMIC DISPATCH

A. Procedure of PSO method for Economic Dispatch: The search procedure of the proposed PSO methods for ED is described as follows:

Step 1

Between maximum and minimum operating limits of generators the particles are randomly generated in economic dispatch.

$$p_i = (p_{i1}, p_{i2}, \ldots\ldots p_{iN}) \rightarrow (4)$$

Step 2

In the range $\left[-V_i^{\max}, V_i^{\max}\right]$ particle velocities are generated.

Step 3

The maximum velocity limits in the i[th] plant is,

$$V_i^{\max} = \frac{P_{i\max} - P_{i\min}}{R} \rightarrow (5)$$

Step 4

The values of the particles are evaluated by the equations 1, 2 and 3.

Step 5

Set the value obtained using the equations 1, 2 and 3 as a P_{best} value of the particle.

Step 6

The best of P_{best} and G_{best} values to be identified

Step 7

New velocities for all dimensions in each particles is calculated using,

$$v_i^{k+1} = w_i v_i^k + (c_x * rand * (pbest_i - s_i^k)) + (c_2 * rand * (gbest_i - s_i^k)) \rightarrow (6)$$

Step 8

The position of the each particle is updated using,

$$w = w_{\max} - \frac{w_{\max} - w_{\min}}{iter_{\max}} * iter \rightarrow (7)$$

Step 9

The new value is set as P_{best}.When the value is better than previous P_{best}, and the objective function values are calculated for the updated position of the particles.

Step 10

If the stopping criteria are met, the positions of particles represented by G_{best} are the optimal solutions. Otherwise, the procedure is repeated from step (6).

B. Procedure of CPSO method for Economic Dispatch

The search procedure of the proposed CPSO methods for ED is described as follows:

Step 1

For every Unit specify lower and upper bound generation power loads.

Step 2

According to the limit of each unit calculate the value of F_{max} and F_{min}.By considering individual dimensions, searching point and velocities.

Step 3
Calculate the transmission loss P_L using the b coefficient loss formula for every individual Pg in the population.
Step 4
Calculate the evaluation value of each individual P_{gi} of the population employing the evaluation function f determined according to the practical conditions.
Step 5
Make the best evaluation value among the P_{best} be P_{gbest} by comparing each individual's evaluation value with its P_{best}.
Step 6
The member velocity [V_{id}] is updated based on equation (8)

$$v_{id}[t+1] = wv_i[t] + c_1 \times rand(.) \times (P_{bestid} - Pg_{id}) + c_2 \times Rand(.) \times (P_{gbestd} - Pg_{id}) \rightarrow (8)$$

Step 7

If, $$V_{id}[t+1] > V_d^{\max}, then V_{id}[t+1] = V_d^{\max} \rightarrow (9)$$

$$V_{id}[t+1] < V_d^{\min}, then V_{id}[t+1] = V_d^{\min} \rightarrow (10)$$

Step 8
The member position [P_{gi}] is updated based on Equation (11)

$$Pg_i[t+1] = Pg_{id}[t] + V_{id}[t+1] \rightarrow (11)$$

Step 9
If the evaluation value of each individual is better than the previous P_{best}, the current Value is set to be P_{best}. If the best is better than P_{gbest}, the value is set to be P_{gbest}.
Step 10
Reserve the top n/5 particles in the population.
Step 11
Update the best particle using the result of Chaotic Local Search with variables. $P_{g,i}^{(k)}$
Step 12
If a stopping criterion is satisfied, output the solution found best so far.
Step 13
Decrease the search space

$$P_{\min i} = \max(P_{\min i}, P_{g,i}^{(k)} - r(P_{\max i} - P_{\min i})) \rightarrow (12) \quad 0 < r < 1$$

$$P_{\max i} = \min(P_{\max i}, P_{g,i}^{(k)} - r(P_{\max i} - P_{\min i})) \rightarrow (13) \quad 0 < r < 1$$

Step 14
Generate randomly 4n/5 new particles within the decreased search space and evaluate them.
Step 15
Reconstruct the new population consisting of the 4n/5 new particles and the old top n/5 particles in which the best particle is replaced by the results of CLS.
Step 16
If the iterations number reaches the maximum, go to step 17. Otherwise, let k=k+1and go back to step 3.
Step 17
The individual that generates the latest P_{gbest} is the optimal generation power of each unit when the system reaches the minimum total generation cost.

C. Procedure of SAPSO method for Economic Dispatch

The search procedure of the proposed SAPSO methods for ED is described as follows:
Step 1
Get the input parameters like range [min max] for each of the variables, C_1, C_2, V_{max}, W_{min} and W_{max} .
Step 2
Initialize n number of population of particles of dimension d_i with random Positions and velocities.
Step 3
Increment iteration counter by one
Step 4
Evaluate the fitness function of all particles in the population.
Step 5
Update its objective value by find particles best Position (P_{best}) of each particle.
Step 6
Update its objective value by find global best position (G_{best}) among all particles.
Step 7
If stopping criterion is met go to step (13). Otherwise continue.
Step 8
Evaluate the inertia factor according to equation (14).

$$w_i = w_{\min} + \frac{(w_{\max} - w_{\min}) * Rank_i}{Totalpopulation} \rightarrow (14)$$

Step 9
Update the velocity using equation (15).

$$v_{ij}(t+1) = w_i v_{ij}(t) + c_1 r_1 (p_{ij}(t) - x_{ij}(t)) + c_2 r_2 (p_{gj}(t) - x_{ij}(t)) \rightarrow (15)$$

Step 10
Correct the updated velocity using equation (16).

$$v_{ij}(t+1) = sign(v_{ij}(t+1)) * \min(|v_{ij}(t+1)|, v_{j\max}) \rightarrow (16)$$

Step 11
Update the position of each particle according to equation (17). $$x_{ij}(t+1) = x_{ij}(t) + v_{ij}(t+1) \rightarrow (17)$$

Step 12
If the new position goes out of range, set it to the boundary value using equation (18).

$$x_{ij}(t+1) = \max(x_{ij}(t+1), range_{j\min}) \rightarrow (18)$$

Step 13
The elites are inserted in the first position of the new population in order to maintain the best particle found so far.
Step 14
For every generations, this $F_{Best,new}$ value (at the end of these 5 generations) is compared with the $F_{Best,old}$ value (at the beginning of these 5 generations), if there is no noticeable change, then re-initialize k% of the population. Go to step (3).
Step 15
Output the G_{best} particle and its objective value.

(vi) GENERATORS DATA [13 UNITS]

- ✓ Total Load Demand [P_D] = 1800 MW
- ✓ Maximum Iteration [I_{max}] = 500
- ✓ Weight Inertia Factors [W_0 , W_f] = 0.9 , 0.4 Respectively.
- ✓ Acceleration Co-efficient [C_1 , C_2] = 1.5 ,1.5 Respectively.
- ✓ Number of Particles [m] = 20

(vii) SIMULATION RESULTS AND DISCUSSION

The coding of the algorithms was done on MATLAB 6.5, and the test system is the IEEE 13 generator system. Each algorithm was run for specified number of iterations and the best value obtained was recorded, along with the graph for the average and minimum value against the number of iterations.

The time of execution for all the three algorithms were measured and recorded. Each algorithm was executed ten times and the best and the worst value were found, the graph for these executions were plotted.

Comparison of Simulation results for 13 generator units (Load=1800MW)

Table 1: Represents generators data [13 units]

Sl. No.	*G*	$P_{min}(MW)$	$P_{max}(MW)$	*a*	*b*	*c*	*e*	*f*
1.	1	0	680	0.00028	8.10	550	300	0.035
2.	2	0	360	0.00056	8.10	309	200	0.042
3.	3	0	360	0.00056	8.10	307	200	0.042
4.	4	60	180	0.00324	7.74	240	150	0.063
5.	5	60	180	0.00324	7.74	240	150	0.063
6.	6	60	180	0.00324	7.74	240	150	0.063
7.	7	60	180	0.00324	7.74	240	150	0.063
8.	8	60	180	0.00324	7.74	240	150	0.063
9.	9	60	180	0.00324	7.74	240	150	0.063
10.	10	40	120	0.00284	8.6	126	100	0.084
11.	11	40	120	0.00284	8.6	126	100	0.084
12.	12	55	120	0.00284	8.6	126	100	0.084
13.	13	55	120	0.00284	8.6	126	100	0.084

Table.2. Represents Comparison of Gen cost

Sl. No	Methods	Minimum Cost	Maximum cost	Mean cost
1.	PSO(Ref)	18014.16	18249.89	18104.65
2.	PSO	18075.00	18328.00	18165.00
3.	CPSO	18080.00	18414.00	18188.00
4.	SAPSO	18083.00	18396.00	18118.00

Table.3. Represents Comparison of Time of execution

Sl. No	Methods	Time of execution
1.	PSO(Ref)	NA
2.	PSO	5.924217 seconds
3.	CPSO	6.222800 seconds
4.	SAPSO	5.905451 seconds

Table.4. Represents Speed of convergence

Sl. No	Methods	Speed of convergence
1.	PSO(Ref)	NA
2.	PSO	350^{th} iteration
3.	CPSO	200^{th} iteration
4.	SAPSO	380^{th} iteration

Table.5. represents best solutions found for 13 generator units

Sl. No.	G	PSO(Ref)	PSO	CPSO	SAPSO
1.	1	538.5610	448.8008	448.7997	359.0340
2.	2	299.3550	149.8741	150.6313	224.3995
3.	3	075.0370	152.6095	151.6313	224.3987
4.	4	159.7340	109.8670	109.8844	109.8508
5.	5	060.0780	109.8672	109.8671	109.8559
6.	6	109.8640	159.7354	109.8672	109.7696
7.	7	109.9130	109.8681	109.8792	109.8554
8.	8	159.7530	109.8699	109.8666	109.8299
9.	9	060.0690	109.8822	159.7332	109.8252
10.	10	040.0350	077.4021	077.4476	108.5065
11.	11	077.5610	077.4137	114.8140	077.2675
12.	12	055.0420	092.4081	092.4075	055.0000
13.	13	055.0000	092.4016	055.0026	092.4070

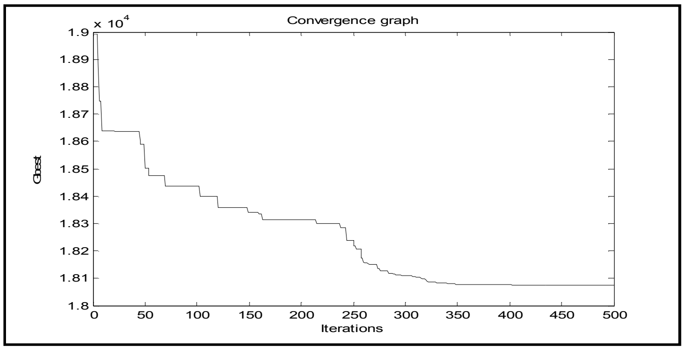

Figure 1: G_{best} Vs Iterations of PSO

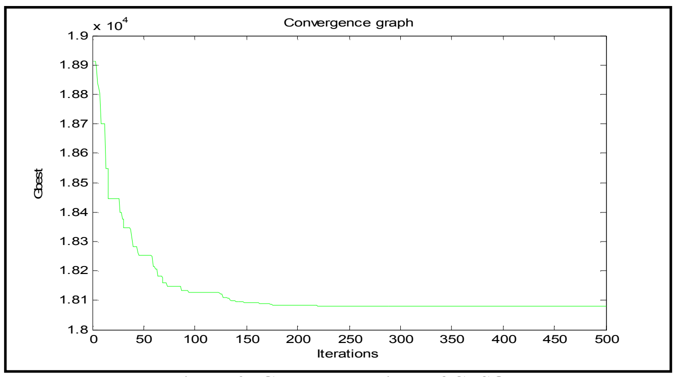

Figure 2: G_{best} Vs Iterations of CPSO

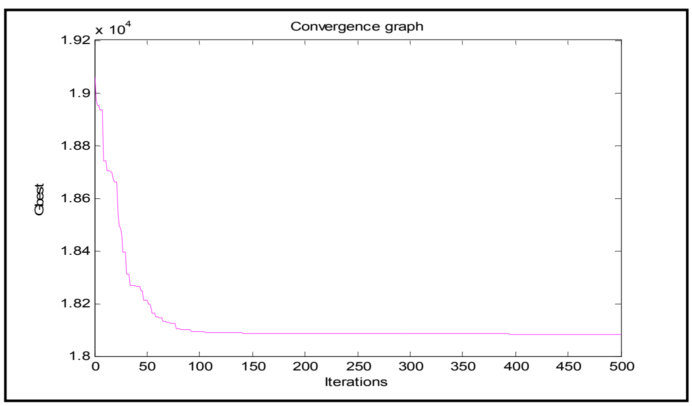

Figure 3: G_{best} Vs Iterations of SAPSO

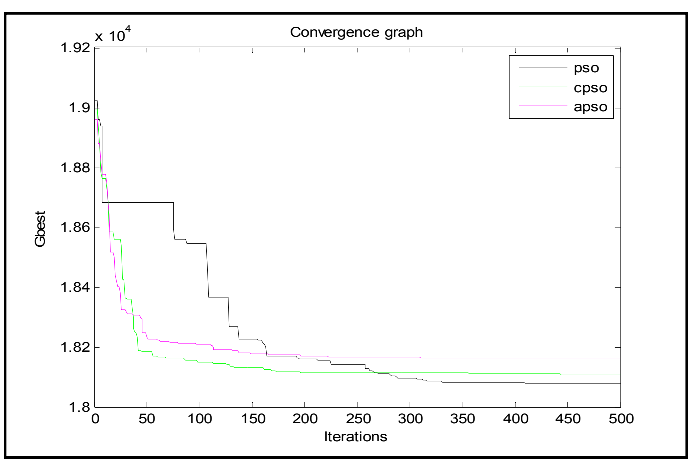

Figure 4: Graph of PSO, CPSO and SAPSO Comparisons

CONCLUSION

The following conclusion were drawn based on the simulation results as shown in the table 2, 3, 4, 5 and Graphs 1, 2, 3 and 4 shows that optimization techniques like PSO, CPSO and SAPSO are evaluated under speed of convergence, time of execution and in terms of minimal fuel cost. A random population is initialized and the fitness value of each is calculated. This paper shows that the proposed approaches can obtain even more optimum solutions than the other methods including evolutionary programming techniques.

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BIOGRAPHIE

Mr.J.Vikramarajan received his Master degree in Power Electronics and Drives and Bachelor degree in Electrical and Electronics Engineering from VIT University, India. His research interests are power electronic applications, power quality, power electronic converters and power electronic controllers for renewable energy systems.

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