Solving Economic Load Dispatch Problem UsingParticle Swarm Optimization Technique

Aditya Tiwari[a], Shanker Godwal[b], Akhilesh Nimje[c]

[a,b,c] Deptt. of Electrical Engineering, Nirma University, Ahmedabad, India
[a] tiwariaditya46@gmail.com, [b] Indiashanker.godwal@nirmauni.ac.in, [c] akhilesh.nimje@nirmauni.ac.in

Article History: Received: 10 November 2020; Revised 12 January 2021 Accepted: 27 January 2021; Published online: 5 April 2021

Abstract: Economic load dispatch (ELD)is one of the important problems ofpower system operation. Conventional methods like Lambda iteration methodare not efficientfor complex ELD problems. Particle swarm optimization is preferred in ELD problem due to its high performance.The Inertia Weight PSO and Constriction Factor PSO algorithms are performed on threeunit and sixunit systems. The analysis of ELD problem is performed by Conventional method and PSO method. In this paper,losses are neglected in the ELD problem. PSO algorithm obtains the best solution forELD problem.

Keywords: Optimization, Economic load dispatch (ELD), Particle swarm optimization (PSO), IPSO, CPSO

1. Introduction

The economic load dispatch problemisone of theoptimization problems. The mainaim of thisproblem is to minimize the total cost of generation.The conventional methods require more computation time in the ELD problem. PSO and Genetic Algorithm methodsare mainly used in ELD problems. The conventional method cannot obtain the best solution tothe ELD problem.PSO is the most efficient methodfor economic load dispatch problem.Various PSO algorithms used in this paper are Inertia weight PSO (IPSO) and Constriction factor PSO (CPSO) algorithm[1].

Various optimization problems are not solved by the single optimization. Different optimization methods are available for various optimization problems. The PSO algorithm offers the best solution for optimization problems. Modern optimization methods like PSO areeffective for engineering problems. The main aspect of PSO algorithm is its simplicity and a relatively less number of parameters.

2. Problem Formulation

The main focusof the ELD problem is to generate power at the minimum cost while satisfying certain constraints.Economic load dispatch determines the optimum share of the power demand subject to various system constraints. The ELD problem is expressed as (1).

$$\text{Min } F_t = \sum_{i=1}^{n} F_i (P_i) \quad (1)$$

$F_i (P_i) = (a_i + b_i{*}P_i + c_i{*}P_i^2)$

Pi - Power generation of ithunit

Ft- Total cost of generation

ai, bi, ci - fuel cost coefficients of ith unit

A. System Constraints

There are two types of constraints.

i) Power balance constraints[2]

In this constraint,power generation is equal to the sum of Power demand and power loss.

$$\sum_{i=1}^{n} P_i - P_D - P_L = 0 \quad (3)$$

Pi- Power generation

PD- Power demand

PL- Power Loss

ii) Inequality constraints[2]

The Output power of each generator should be between its lower limit and upper limit.

Pimin≤ Pi≤ Pimax (4)

Pimin - Minimum output power of ith generator

Pimax - Maximum output power of ith generator

Pi - Output power of ith generator

3. Particle Swarm Optimization

The concept of PSO was developed by Kennedy and Eberhart. In PSO, a swarm consists of several particles. The PSO technique is based on the representation of social psychology. Each particle in PSO has a random position and random velocity. Each particle searches for a speed-adjusted position based on their flying and neighbourhood flying experience. If one particle first finds the best path to food then other particles will quickly follow the best path.The parameters that affect the performance of PSOare Swarm size, Number of iterations and Acceleration coefficients.

A. Computational Procedure of PSO [3]

The various steps of the PSO algorithm are as follows.

1. Parameter selection

Selection of PSO parameters such as population size, maximum iteration and acceleration constant.

2. Initialization of Population

In PSO,the particles are initialized with position p within the generator limits and velocity V.

3. Evaluation of Objective function

Calculate the fuel cost of the plant for each particle with the help of generated output power.

4. Selection of Previous best and Global best position

Set the initial output power for every particle to its previous best and set the best of the previous best to the global best.

5. Velocity and Position updation

Calculate the updated Position and Velocity of the particle.

6. Termination step

The PSO algorithm stops after a sufficient best fitness or maximum iterations are reached.

4. Methods For Eld Problem

A. Inertia weight Particle Swarm Optimization

Shi and Eberhart [4] developed Inertia weight PSO to enhancethe performance of PSO. This algorithm is known as Inertia weight PSO (IPSO). The inertia weight w is used to limit the velocity below its maximum value. This method enables the faster convergence of the swarm. The equations used in this algorithm are (5) and (6) respectively.

$$V_i^{t+1} = w * V_i^t + r1 * c1 * (pbest_i - x_i^t) + c2 * r2 * (gbest_i - x_i^t) \quad (5)$$

$$x_i^{t+1} = x_i^t + V_i^{t+1} (6)$$

$$w = w_{max} - \frac{(w_{max} - w_{min})*t}{it_{max}} (7)$$

Acceleration constantsc1=c2= 2,weight factor wmax= 0.9 and wmin= 0.4. wmax and wmin are maximum and minimum weight factor, t and itmax are current iteration and maximum iteration.〖V〗_i^(t+1) and x_i^(t+1) are current velocity and position of particle respectively.

B. Constriction factor Particle swarm optimization

After the standard PSO algorithm, various PSO algorithms were introduced. Clerc [5] developed a Constriction factor PSO (CPSO) algorithm to improve the PSO performance. Constriction factor k is included to increase the convergence rate of PSO. The equations used in this algorithm are (8) and (9) respectively.

$$V_i^{t+1} = K * [V_i^t + c1 * r1 * (pbest_i - x_i^t) + c2 * r2 * (gbest_i - x_i^t)] \quad (8)$$

$$x_i^{t+1} = x_i^t + V_i^{t+1} (9)$$

$$K = \frac{2}{[2 - \emptyset - \sqrt{\emptyset^2 - 4\emptyset}]} \quad (10)$$

Acceleration constants c1 = c2 = 2.05 and Constriction factor K = 0.729.〖 V〗_i^(t+1)andx_i^(t+1)are current velocity and position of particle respectively.

5 Results

A. Case Study 1: 3 UNIT SYSTEM

In this case study three unit thermal system is considered. All units have the minimum and maximum generation limits. The generation data of three unit thermal system without lossis given in Table I[6].

TABLE I - GENERATION DATA FOR 3 UNIT SYSTEM

UNIT	**a**	**b**	**c**	p_{min}	p_{max}
1	561	7.92	0.00156	100	600
2	310	7.85	0.00194	100	400
3	78	7.97	0.00482	50	200

PARAMETERS OF PSO FOR 3 UNIT SYSTEM

Population size = 200

Maximum iteration = 100

wmax = 0.9, wmin = 0.4 for IPSOALGORITHM

Acceleration constant c1= c2 =2 for IPSO ALGORITHM

c1= c2 =2.05 for CPSO ALGORITHM

TABLE II - CONVENTIONAL METHOD FOR 3 UNIT SYSTEM

S NO	**DEMAND (MW)**	**P1 (MW)**	**P2 (MW)**	**P3 (MW)**	**TOTAL COST (RS./HR)**
1	600	275.94	239.93	84.12	5953
2	700	322.94	277.72	99.33	6838.4
3	800	369.93	315.51	114.54	7738.5
4	850	393.43	334.41	122.14	8194
5	1050	487.43	409.996	152.57	10053

TABLE III -INERTIA PSO ALGORITHM FOR 3 UNIT SYSTEM

S NO	**DEMAND (MW)**	**P1 (MW)**	**P2 (MW)**	**P3 (MW)**	**TOTAL COST (RS./HR)**
1	600	273.976	241.193	84.738	5952.193
2	700	321.160	277.502	101.251	6837.671
3	800	368.985	317.457	113.467	7737.696
4	850	395.	333.	121.	8193.2

		659	201	055	97
5	1050	494.028	400	155.880	10052.337

TABLE IV - CONSTRICTION PSO ALGORITHM FOR 3 UNIT SYSTEM

S NO	DEMAND (MW)	P1 (MW)	P2 (MW)	P3 (MW)	TOTAL COST (RS./HR)
1	600	277.127	238.773	84.010	5952.218
2	700	323.521	277.172	99.221	6837.655
3	800	370.354	315.464	114.085	7737.632
4	850	393.626	333.985	122.298	8193.229
5	1050	495.005	400	154.900	10052.294

TABLE V - COMPARISON OF COST FOR 3 UNIT SYSTEM

S NO	DEMAND (MW)	CONVENTIONAL (RS./HR)	INERTIA PSO (RS./HR)	CONSTRICTION PSO (RS./HR)
1	600	5953	5952.193	5952.218
2	700	6838.4	6837.671	6837.655
3	800	7738.5	7737.696	7737.632
4	850	8194	8193.297	8193.229
5	1050	10053	10052.337	10052.294

B. Case Study 2: 6 UNIT SYSTEM

In this case study six unit thermal system is considered. All units have the minimum and maximum generation limits. The generation data of six unit thermal system without lossis given in Table II[7].

TABLE VI - GENERATION DATA FOR 6 UNIT SYSTEM

UNIT	a	b	c	p_{min}	p_{max}
1	240	7	0.0070	100	500
2	200	10	0.0095	50	200
3	220	8.5	0.0090	80	300
4	200	11	0.0090	50	150
5	220	10.5	0.0080	50	200

6	190	12	0.0075	50	120

PARAMETERS OF PSO FOR 6 UNIT SYSTEM

Population size = 150

Maximum iteration = 200

Inertia factor wmax = 0.9, wmin = 0.4 for IPSO ALGORITHM

Acceleration constant c1= c2 =2 for IPSO ALGORITHM

c1= c2 =2.05 for CPSO ALGORITHM

TABLE VII– CONVENTIONAL METHOD FOR 6 UNIT SYSTEM

S NO	DEMAND (MW)	P1 (MW)	P2 (MW)	P3 (MW)	P4 (MW)	P5 (MW)	P6 (MW)	TOTAL COST (RS./HR)
1	1080	410.830	144.822	236.201	97.312	140.726	50.108	12896
2	1150	424.553	154.934	246.875	107.986	152.734	62.916	13796
3	1240	442.198	167.935	260.598	121.709	168.173	79.384	14972
4	1300	453.961	176.602	269.747	130.858	178.466	90.363	15768
5	1400	473.566	191.048	284.995	146.107	195.620	108.661	17117

TABLE VIII - INERTIA PSO ALGORITHM FOR 6 UNIT SYSTEM

S NO	DEMAND (MW)	P1 (MW)	P2 (MW)	P3 (MW)	P4 (MW)	P5 (MW)	P6 (MW)	TOTAL COST (RS./HR)
1	1080	413.610	145.237	233.266	96.121	141.606	50	12894.559
2	1150	421.145	155.534	250.886	108.116	155.882	58.284	13794.268
3	1240	450.595	171.664	263.586	114.278	161.163	78.524	14970.939
4	1300	448.389	175.016	270.918	131	181.598	92.898	15766.199
5	1400	474.181	189.808	287.724	142.866	200	105.266	17115.792

TABLE IX - CONSTRICTION PSO ALGORITHM FOR 6 UNIT SYSTEM

S NO	DEMAND (MW)	P1 (MW)	P2 (MW)	P3 (MW)	P4 (MW)	P5 (MW)	P6 (MW)	TOTAL COST

								(RS./HR)
1	1080	408.932	145.812	237.745	97.320	140.029	0	12894.451
2	1150	427.057	153.421	246.861	110.115	151.518	60.858	13793.755
3	1240	443.613	166.891	259.850	121.413	169.102	78.959	14969.620
4	1300	455.288	177.551	268.597	130.565	178.599	89.246	15766.237
5	1400	473.373	190.956	284.833	146.282	195.477	108.867	17114.617

TABLE X - COMPARISON OF TOTAL COST FOR 6 UNIT SYSTEM

S NO	DEMAND (MW)	CONVENTIONAL (RS./HR)	INERTIA PSO (RS./HR)	CONSTRICTION PSO (RS./HR)
1	1080	12896	12894.559	12894.451
2	1150	13796	13794.268	13793.755
3	1240	14972	14970.939	14969.620
4	1300	15768	15766.199	15766.237
5	1400	17117	17115.792	17114.617

6 CONCLUSION

In this paper, the ELD problem is solved using the conventional method and various PSO algorithms. The two test systems taken for the ELD problem are threeunit system and the sixunit system.The total cost is minimum in the PSO algorithm as compared to Conventional lambda iteration method.CPSO algorithm provides a faster convergence rate compared to the IPSO algorithm.It is concluded that both IPSO and CPSO algorithm gives the best solution for ELD problem.The total cost reductionis more inthe six-unit system than the three-unit system.

References

Puri, V., Chauhan, Y. K., & Singh, N. (2016). Economic load dispatch problem using particle swarm optimization with inertial weight and constriction factor. Science & Technology Asia, 52-60.

Ahmad, A., Singh, N., & Varshney, T. (2011). A New approach for solving economic load dispatch problem. MIT International Journal of Electrical and Instrumentation Engineering, 1(2), 93-98.

Kumar, N., Pal, N., Kumar, P., & Kumari, A. (2018, March). Impact of different inertia weight functions on particle swarm optimization algorithm to resolve economic load dispatch problems. In 2018 4th International Conference on Recent Advances in Information Technology (RAIT) (pp. 1-5). IEEE.

Shi, Yuhui, and Russell Eberhart. "A modified particle swarm optimizer." 1998 IEEE international conference on evolutionary computation proceedings. IEEE world congress on computational intelligence (Cat. No. 98TH8360). IEEE, 1998.

Clerc, M., & Kennedy, J. (2002). The particle swarm-explosion, stability, and convergence in a multidimensional complex space. IEEE transactions on Evolutionary Computation, 6(1), 58-73.

Sudhakaran, M., Raj, P. A. D. V., & Palanivelu, T. G. (2007, November). Application of particle swarm optimization for economic load dispatch problems. In 2007 International Conference on Intelligent Systems Applications to Power Systems (pp. 1-7). IEEE.

Maan, R. S., Mahela, O. P., & Gupta, M. (2013). Economic load dispatch optimization of six interconnected generating units using particle swarm optimization. IOSR J. Electr. Electron. Eng., 6(2), 21-27.

Hardiansyah, J., & Yohannes, M. S. (2012). Solving economic load dispatch problem using particle swarm optimization technique. IJ Intelligent Systems and Applications, 12, 12-18.

Kaur, G., & Kumar, D. (2014). Economic Load Dispatch Problem Using Particle Swarm Optimization Technique: A Review. An International Journal of Engineering Sciences, 3(1), 31-36.

Saadat, Hadi. "'Power System Analysis', Tata McGraw Hill Publishing Company, New Delhi, 2002." (2015).

Pranava, G., & Prasad, P. V. (2013, February). Constriction coefficient particle swarm optimization for economic load dispatch with valve point loading effects. In 2013 International Conference on Power, Energy and Control (ICPEC) (pp. 350-354). IEEE.

Dasgupta, K., & Banerjee, S. (2014, January). An analysis of economic load dispatch using different algorithms. In 2014 1st International Conference on Non-Conventional Energy (ICONCE 2014) (pp. 216-219). IEEE.

Park, J. B., Jeong, Y. W., Shin, J. R., & Lee, K. Y. (2009). An improved particle swarm optimization for nonconvex economic dispatch problems. IEEE Transactions on power systems, 25(1), 156-166.

Kumar, N., Nangia, U., & Sahay, K. B. (2014, December). Economic load dispatch using improved particle swarm optimization algorithms. In 2014 6th IEEE Power India International Conference (PIICON) (pp. 1-6). IEEE.