OPTIMIZATION OF ECONOMIC LOAD DISPATCH PROBLEM BY GA AND PSO - A COMPARISON

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Abstract – *In this paper, a comparative study of the two very popular methods, the Genetic Algorithm (GA) and the Particle Swarm Optimization (PSO), for determining the solution of an Economic Dispatch problem. The feasibility of both the methods is demonstrated for a six-generator system, a fifteen- generator system and a forty- generator system. The experimental results obtained from the above test systems show that the solution obtained by PSO for the given Economic Dispatch problem are better than that obtained by using the Genetic Algorithm technique.*

Key Words: Economic Dispatch problem, System Constraints, Power Systems, Load demand.

1. INTRODUCTION

The most economical way to meet the load demand while meeting all the system constraints is known as Economic Dispatch (ED). Put differently, Economic Load Dispatch is a problem of determining the power output of each generating unit of the power system such that the total fuel cost is minimum while all the system constraints are like generation limits, valve point loading effects, etc. are taken care of. The problem of determining the outputs of the generating units at minimum cost is known as Optimal Power Flow (OPF) problem.

The production cost of any generator is unique and is a quadratic function of power generated by it. For a given power generated by the unit, a unique cost is incurred. The minimum cost incurred for all the units combined together becomes the optimization problem which is known as the ED problem.

Subham Sahoo et al. have given a comparative study of the three very popular methods for optimization, Cuckoo Search, GA and the PSO [1]. They have considered a three-unit and a six-unit test system for their experiment and have come up with the best possible outcomes.

J. S. Luo has proposed an approach to economic dispatch with the bus incremental cost as most crucial variable which offers a possibility of getting an insight of the ED mechanism [2]. To solve the ED problem, they have used the bus incremental cost as a key variable. They have also taken into account the generation limits while solving the problem.

H.H. Happ gives a review on the progress of optimal dispatch (ED) problem [3]. They have considered both, single area as well as multi-area case and have come up with some theoretical results.

Genetic algorithm is an old but very important tool for solving the problem of economic load dispatch. Walters and Sheble propose to solve the ED problem with a GA based algorithm [4]. Similarly, Karzarlis et al. give a GA based solution to a problem of Unit commitment [5]. The GA algorithm uses the standard crossover and mutation operators to determine a solution in the proximity of the optimal solution. The test system of up to 100 units have been taken and results are reported. C.L. Chiang has come up with a new GA with multiplier updating [6]. This algorithm has been used to solve the ED problems with valve loading effects. He has taken a system with multiple fuels and compared the results of his method with the conventional GA method. A.A. Abou El Ela et al. propose three GA based procedures to minimize transmission line losses and to control overloading of the lines [7]. They carry out simulations to validate their proposed procedures.

PSO is comparatively recent tool for solving the optimization problems in the field of power system. Zwe-Lee Gaing gives a PSO for the optimization of the ED problem [8]. He has taken into account all the nonlinearities in the problem. He has taken three different test systems to validate his results.

Jinn Tsai et al. have proposed a Taguchi-based PSO for the solution of a flowshop scheduling problem [9]. They try to prove that the TBOPSO gives better results than the other conventional methods for the solution of same problem. C Dhifaoui et al., in their paper, have come up with a new method to solve the problem of ED [10]. They have tried to solve the problem via unit commitment. They have performed their experiment on a thirty-nine bus system to justify their claim.

Valve point loading effect must be taken into consideration while solving the ED problem. Classical PSO converges prematurely towards the solution and hence the best solution is not obtained. So, new factors must be added in the classical PSO to get the solution like using time varying acceleration coefficients or using differential evolution [11, 12].

2. OVERVIEW OF PARTICLE SWARM OPTIMIZATION

James Kennedy and Russ Eberhart, in 1995, came up with an optimization technique called Particle Swarm Optimization (PSO) [13, 14]. It is a very simple but powerful technique used for solving optimization problems. Its source of inspiration was the social behavior of a flock of bird. In PSO,

each single solution is a "bird" in the search space. We call it "particle". The fitness function, which is the function to be optimized, evaluates the fitness value of each individual (Particle). These particles also have velocities which influences the flying of these particles. The particles fly through the problem space by following the current optimum particles.

Initially, in PSO, the system starts with a group of population of random solutions. It then moves towards the optimal solution with certain velocity which is influenced by its own flying experience and the flying experience of the entire flock. The best solution obtained by a given particle is called particle best solution, represented by pbest and the best solution obtained so far in the entire group is called global best solution, and is denoted by gbest.

Let x denotes the position of a particle and v denotes its flight velocity. In a d- dimensional space, pbest denotes the previous best position of the particle and and gbest denotes the best position obtained by all particles so far. The updated position and velocity of each particle can be calculated using its current velocity and its distance from the gbest as:

- Updated Velocity, $v_i(n+1) = w * v_i(n) + C_1 * (pbest_i — x_i(n)) + C_2 * (gbest — x_i(n))$
- Updated Position, $x_i(n + 1) = x_i(n) + v_i(n + 1)$

i — particle index

n — discrete time index

w — inertia weight factor

v_i — velocity of i^{th} particle

x_i — position of i^{th} particle

$pbest_i$ — best known position known by the i^{th} particle

gbest — best known position known by the swarm

C_1, C_2— acceleration constant.

With the addition of w, known as inertia weight factor, the PSO is modified and the number of iterations are reduced. The acceleration constants C_1 and C_2 pull each particle towards the particle and global best positions. Lower values of C_1 and C_2 let the particles roam away from the target region while the higher values leads to their abrupt movement towards the target region. Typically, both C_1 and C_2 are given a value of 2.

3. OVERVIEW OF GENETIC ALGORITHM

Genetic Algorithm (GA) is a probabilistic search algorithm. It is based on the mechanics of natural selection. According to the concept of natural selection, given by Charles Darwin, fittest individuals dominate over the weaker ones while competing for limited resources. Prof. John Holland, his colleagues and students came up with the GA in 1975.

The GA is one of the most widely used methods for solving both constrained and unconstrained optimization problems [15, 16]. In genetic algorithm, initial population is randomly selected in the beginning. This population gets modified in the successive steps. The next generation is an offspring of the previous generation which is formed from the better genes of the latter. With every new generation, the population (solution) gets better and moves towards the optimal solution.

Basically, there are mainly three rules at each step for producing the future generation from the current population:

- Selection rules: individuals are selected which act as parents contributing to the population at the next generation.
- Crossover rules: two parents combine to produce the next generation.
- Mutation rules: apply random changes to individual parents to form children.

The GA maintains a population of chromosomes (solutions) with associated fitness values. Based on the fitness level of the parents, they are chosen to mate and produce the future generation (solutions). It means the fitter solutions get more opportunities to mate, and hence the offspring, after inheriting the characteristics from each parent, is better than its previous generation. In this way, the successive generations improves towards the optimal solution and the poorer solutions die out vanish.

4. NUMERICAL EXAMPLES AND RESULTS

The Economic Dispatch (ED) problem is solved by the PSO and the GA method and the results obtained are discussed and compared. Two different systems, having six and fifteen generators, are taken as the test system. For simplicity, the ramp rate limits, losses, and the prohibited zones are not considered. Under the same evaluation function and individual definition, we perform 50 trials using the above methods and the quality of the solution is observed.

1) PSO Method:
   - Population size = 100
   - Generations = 200
   - Inertia weight factor: w_{max} = 0.9 and w_{min} = 0.4
   - Acceleration constants: C_1 =2 and C_2 =2.
2) GA Method:
   - Population size = 100
   - Generations = 200
   - Crossover rate, P_c =0.8
   - Mute rate, P_m = 0.01

Case Study

Example 1: Six-Unit system: The test taken into consideration system consists of six generators for a load demand of 1263 MW on the system. The characteristics of the six units are given in table 1. The power outputs of the six generators are represented by P_1, P_2, P_3, P_4, P_5 and P_6. These values are randomly generated. The best solution obtained by applying these methods is shown in table 2.

Table-1: Generating unit data

Unit	P_i^{min}	P_i^{max}	α_i ($)	β_i ($/MW)	γ_i ($/MW^2)
1	100	500	240	7.0	0.0070
2	50	200	200	10.0	0.0095
3	80	300	220	8.5	0.0090
4	50	150	200	11.0	0.0090
5	50	200	220	10.5	0.0080
6	50	120	190	12.0	0.0075

Table-2: Optimum solution of 6- unit system

Unit Power Output	PSO	GA
P_1(MW)	447.9250	445.8835
P_2(MW)	170.6501	170.3555
P_3(MW)	264.7467	267.1309
P_4(MW)	120.3847	120.6641
P_5(MW)	170.8557	170.3184
P_6(MW)	88.4368	88.6466
Total Power output (MW)	1263	1263
Total Generation cost ($/hr)	15,276	15,276

Table-3: Comparison between both methods (50 trials)

	Generation cost ($)	
	Max	**Min**
PSO	15298	15276
GA	15277	15276

Example 2: Fifteen-Unit System: The system consists of fifteen generators and the total load demand on the system is 2630 MW. The characteristics of the fifteen generators are given in table 4. The results of the experiment are shown in Tables 5 and 6. These results are found to satisfy the system constraints.

Table-4: Generating unit data

Unit	P_i^{min}	P_i^{max}	α_i ($)	β_i ($/MW)	γ_i ($/MW^2)
1	150	455	671	10.1	0.000299
2	150	455	574	10.2	0.000183
3	20	130	374	8.8	0.001126
4	20	130	374	8.8	0.001126

5	150	470	461	10.4	0.000205
6	135	460	630	10.1	0.000301
7	135	465	548	9.8	0.000364
8	60	300	227	11.2	0.000338
9	25	162	173	11.2	0.000807
10	25	160	175	10.7	0.001203
11	20	80	186	10.2	0.003586
12	20	80	230	9.9	0.005513
13	25	85	225	13.1	0.000371
14	15	55	309	12.1	0.001929
15	15	55	323	12.4	0.004447

Table-5: Optimum solution of 15- unit system

Unit Power Output	PSO	GA
P_1(MW)	343.9627	270.8264
P_2(MW)	452.0160	268.2754
P_3(MW)	112.8241	118.1084
P_4(MW)	127.3678	119.0828
P_5(MW)	260.6972	460.6699
P_6(MW)	402.4683	459.2369
P_7(MW)	436.8479	269.2358
P_8(MW)	125.3228	78.4970
P_9(MW)	65.0803	149.0780
P_{10}(MW)	30.5095	147.0860
P_{11}(MW)	68.2176	67.5806
P_{12}(MW)	61.9314	68.0805
P_{13}(MW)	67.8161	71.3302
P_{14}(MW)	40.8083	41.0806
P_{15}(MW)	34.1232	41.8306
Total Power output (MW)	2630	2630
Total Generation cost($/hr)	32,604	32,844

Table-6: Comparison between both methods (50 trials)

	Generation cost ($)	
	Max	**Min**
PSO	32803	32604
GA	33054	32844

Example 3: Forty-Unit System: The system consists of forty generators for a load demand of 7550 MW on the system. The characteristics of the fifteen generators are given in table 7. The results of the experiment are shown in Tables 8 and 9. These results are found to satisfy the system constraints.

Table-7: Generating unit data

Unit	P_i^{min}	P_i^{max}	α_i ($)	β_i ($/MW)	γ_i ($/MW^2)
1	40	80	170.44	8.336	0.03073
2	60	120	309.54	7.0706	0.02028
3	80	190	369.03	8.1817	0.00942
4	24	42	135.48	6.9467	0.08482
5	26	42	135.19	6.5595	0.09693
6	68	140	222.33	8.0543	0.01142
7	110	300	287.71	8.0323	0.00357
8	135	300	391.98	6.999	0.00492
9	135	300	455.76	6.602	0.00573
10	130	300	722.82	12.908	0.00605
11	94	375	635.2	12.986	0.00515

12	94	375	654.69	12.796	0.00569
13	125	500	913.4	12.501	0.00421
14	125	500	1760.4	8.8412	0.00752
15	125	500	1728.3	9.1575	0.00708
16	125	500	1728.3	9.1575	0.00708
17	125	500	1728.3	9.1575	0.00708
18	220	500	647.85	7.9691	0.00313
19	220	500	649.69	7.955	0.00313
20	242	550	647.83	7.9691	0.00313
21	242	550	647.83	7.9691	0.00313
22	254	550	785.96	6.6313	0.00298
23	254	550	785.96	6.6313	0.00298
24	254	550	794.53	6.6611	0.00284
25	254	550	794.53	6.6611	0.00284
26	254	550	801.32	7.1032	0.00277
27	254	550	801.32	7.1032	0.00277
28	10	150	1055.1	3.3353	0.52124
29	10	150	1055.1	3.3353	0.52124
30	10	150	1055.1	3.3353	0.52124
31	20	70	1207.8	13.052	0.25098
32	20	70	810.79	21.887	0.16766
33	20	70	1247.7	10.244	0.2635
34	20	70	1219.2	8.3707	0.30575
35	18	60	641.43	26.258	0.18362
36	18	60	1112.8	9.6956	0.32563
37	20	60	1044.4	7.1633	0.33722
38	25	60	832.24	16.339	0.23915
39	25	60	832.24	16.339	0.23915
40	25	60	1035.2	16.339	0.23915

Table-8: Optimum solution of 40- unit system

Unit Power Output	PSO	GA
P_1(MW)	51.6495	69.899
P_2(MW)	106.4366	115.095
P_3(MW)	146.4114	184.555
P_4(MW)	33.1208	37.332
P_5(MW)	26.3967	36.099
P_6(MW)	133.1878	137.12
P_7(MW)	202.4194	248.282
P_8(MW)	225.0944	245.118
P_9(MW)	235.1695	246.857
P_{10}(MW)	229.7413	249.619
P_{11}(MW)	185.3917	321.446
P_{12}(MW)	136.9803	254.599
P_{13}(MW)	271.3692	244.791
P_{14}(MW)	318.5009	252.566
P_{15}(MW)	181.9445	255.925
P_{16}(MW)	231.3118	249.32
P_{17}(MW)	278.4898	250.376
P_{18}(MW)	318.7897	281.582
P_{19}(MW)	399.5334	388.831
P_{20}(MW)	420.4946	411.776
P_{21}(MW)	434.0356	312.837
P_{22}(MW)	427.1164	319.096
P_{23}(MW)	433.4655	314.376
P_{24}(MW)	391.3355	314.82

P_{25}(MW)	423.9103	315.192
P_{26}(MW)	411.3608	334.909
P_{27}(MW)	447.4497	323.329
P_{28}(MW)	28.8625	101.964
P_{29}(MW)	21.0774	34.159
P_{30}(MW)	32.5027	118.372
P_{31}(MW)	43.2138	63.28
P_{32}(MW)	45.0267	63.669
P_{33}(MW)	35.4292	64.589
P_{34}(MW)	22.5218	62.689
P_{35}(MW)	20.8390	53.239
P_{36}(MW)	38.5331	54.849
P_{37}(MW)	27.0108	53.643
P_{38}(MW)	43.3273	54.003
P_{39}(MW)	46.9845	55.095
P_{40}(MW)	43.1169	54.700
Total Power output (MW)	7550	7550
Total Generation cost($/hr)	110820	129665

Table-9: Comparison between both methods (50 trials)

	Generation cost ($)	
	Max	**Min**
PSO	115730	110820
GA	148187	129665

V. CONCLUSION

In this paper, Particle Swarm Optimization (PSO) and Genetic Algorithm (GA) have been successfully implemented to solve the Economic Dispatch problem with generator constraints. For simplicity, some of the nonlinearities like valve point zones and ramp rate limits have not been considered. For the testing of the above two methods, a six, fifteen and a forty- generator system have been used. The results obtained show that PSO gives better solution than the GA.

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