DIVERSIFIED SOFT COMPUTING TECHNIQUES SOLUTION FOR ECONOMIC LOAD DISPATCH PROBLEM

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ABSTRACT

The electricity consumption increases day by day, and we cannot imagine our lives without electricity. In today's scenario, the electricity should be available to all the consumers at minimum cost. So Economic Dispatch is a vital optimization problem in power system planning. The objective function of the economic load dispatch problem is highly non-linear. Consequently, standard optimization procedures may diverge or trap in local minima. This paper presents an overview of the economic dispatch problem, its formulation, and a comparison of addressing the issue with diversified soft computing techniques, i.e., differential evolution (D.E.), artificial bee colony algorithm (A.B.C.), particle swarm optimization (PSO), firefly algorithm (F.F.), Invasive weed optimization(I.W.O.), social group optimization(S.G.O.) and shuffled complex evolution(S.C.E.). All the methods are tested on 6-units, 7- units, and ten units test systems.

Keywords: *Economic Load Dispatch (ELD), Cost, Differential Evolution, Artificial Bee Colony Algorithm, Particle Swarm Optimization, Firefly Algorithm, Invasive Weed Optimization, Social Group Optimization, And Shuffled Complex Evolution.*

1. INTRODUCTION

In recent years, the electrical power market has become more viable and open to rising energy demand. ELD is an effective technique in operating and planning a modern energy management system. It plays a critical function in the power system's economy. A proper load dispatch maximizes the energy capabilities of thermal units by lowering production costs and increasing system dependability. The ELD process's primary aim is to plan the power system control variables to distribute the total load as efficiently as possible while adhering to all equality and inequality constraints [1-3].

The problem relates with conventional ELD; a unique quadratic function approximates each generator's cost function. The issue was resolved using mathematical programming techniques, including lambda-iteration, gradient, and diverse, dynamic programming approaches.

Many mathematical assumptions are essential, such as convexity, quadratic, differentiable, or linear objectives. Some traditional optimization approaches require derivative information from the objective function to establish the search direction. However, real-world fuel cost functions are non-linear, non-convex, and non-differentiable, with several local minima.

More soft computing solutions have been utilized to solve various non-linear optimization problems. In this paper, the ELD problem has been solved using seven different weak computing schemes such as DE [4], PSO [5], A.B.C. [6], F.F. [7], I.W.O. [8], S.G.O. [9], and S.C.E. [10] with three different test systems consisting of 6, 7 and 10 thermal units.

ELD problems can be solved with various optimization techniques. In the paper [9], ELD is solved using social group optimization. This approach commonly deals with the nature of the social grouping of persons. In the form [8], invasive weed technology is applied to solve the P.I.D. Controller parameters of A.G.C., This Invasive weed optimization technique is used to solve the ELD technique.

Here we have considered the various optimization techniques already proposed earlier along with the I.W.O. and the proposed S.G.O. algorithm for the comparison.

2. MATHEMATICAL FORMULATION

Operating costs play an essential role in economic planning and are discussed here. Factors that affect power generation at the lowest cost are generator operating efficiency, fuel costs, and transmission losses. The most efficient generators in the system may be in areas with high fuel costs and do not guarantee minimum costs. Even if the system is far from the load center, transmission losses can be significantly higher, making the system overly uneconomical. This section deals with the ELD problem as it is written without taking into account transmission losses.

The main goal of ELD is to examine each system's significant possible power value to lessen the cost of inequality and equality constraints. When the number of generators used to create electricity in thermal power plants is N, and the power demand is P.D., the problem can be solved using the objective function shown below

$$F_T = \sum_{i=1}^{n} F(P_i) = \sum_{i=1}^{n} (a_i P_i^2 + b_i P_i + c_i)$$

-- (1)

Where total fuel cost of generation is in the system (\$/hr.), a_i, b_i and c_i are the cost coefficients of the generator, P_i is the power generated by the i^{th} unit, and n is the number of generators. F_T Is the total cost to be minimized subjected to the following generator capacities and active power balance constraints.

(i) $P_{i,\min} \le P_i \le P_{i,\max} \, for\, i = 1, 2, \ldots n$ --(2)

Where $P_{i,\min}$ and $P_{i,\max}$ are the tiniest and extreme power output of the i^{th} unit.

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

where P_D is the total power demand

3. VARIOUS METHODS IMPLEMENTED

PSO is established on swarm movement and intelligence. It uses the concept of social interaction to solve problems. It deals with the random initialization of position and velocity. We will update the best part based on fitness values in every iteration.

D.E is a metaheuristic search algorithm that optimizes problems by repeatedly improving candidate solutions based on the evolutionary process. The differential evolution optimization process uses three basic operations: mutation, crossover, and selection.

The main steps of the A.B.C. algorithm are to initialize the food sources for all employed bees. After that, each employed bee goes to a food source in her memory, determines the closest source, and then evaluates its nectar amount and dances in the hive.

F.F. deals with the initialization of fireflies, calculating the light intensity values and absorption coefficient. After that, we will update the light intensity by tuning the attractive parameter and evaluate the new solution in the iterative process until the final solution is obtained [22].

I.W.O starts with the Random initialization of weeds and their position then calculates the fitness of each weed. Based on the reproduction of weeds, fitness, and their distribution into space, we will find the best fitness until a maximum number of plants will not exceed the limit; we will eliminate the weeds based on fitness.

S.C.E. starts deals with is random creation of individuals, investigation of the objective function, arranging of the individuals and sorting them, division of individuals into complexes after that modification of complex based on Downhill simplex method and sort the complexes in the ascending values of the function, this is repeated until the outcome is satisfying.

S.G.O. can be easily understood by dividing it into two parts. The first part comprises the 'improving phase'; the second includes the 'acquiring phase.' In the 'improving phase,' the person's knowledge level is improved with the control of the most acceptable person in the group. In the 'acquiring phase,' each person enhances their knowledge with the mutual communication with another person in the group and the most acceptable person in the group now. The most delicate person in the group has the utmost knowledge and capability to solve the problem[23].

3. RESULTS AND DISCUSSIONS

Three case studies were considered in this paper. Six generator system (IEEE -30 Bus data), seven generator system (IEEE -57 Bus data), as well as ten generator system (IEEE – 75 Bus data). This work aims to extract power from individual units to satisfy the demand for the lowest possible cost. For the lossless network, all of the approaches were used. Tables 1, 3, and 5 exhibits 6 generator systems, 7 generator systems, and 10 generator systems, respectively. Tables 2, 4, and 6 illustrate the findings for generator systems with 6, 7, and 10 generators, respectively. Throughout this article, different algorithms are used to compare fuel cost, generation of units, and execution time for the three tests mentioned.

Table 1:Case 1: Data for 6 unit system

Generator Number	a	b	c	Pg_{min}	Pg_{max}
1	37.5	200	0	0.50	2.00
2	175	175	0	0.20	0.80
3	83.4	325	0	0.10	0.35
4	250	300	0	0.10	0.30
5	625	100	0	0.15	0.50
6	250	300	0	0.12	0.40

Table 2. Results for Case 1: 6 unit system

Technique	P-G1	P-G2	P-G3	P-G4	P-G5	P-G6	COST	Time for execution
PSO	1.854	0.4687	0.10	0.1	0.1912	0.12	767.6021	0.543838
DE	1.854	0.4687	0.10	0.1	0.1912	0.12	767.6021	0.846968
ABC	1.865	0.4574	0.10	0.1	0.1914	0.12	767.6294	1.388276
FF	1.854	0.4687	0.10	0.1	0.1912	0.12	**767.6021**	**1.513029**
SGO	1.643	0.5859	0.12	0.1	0.2391	0.14	**767.6021**	**1.360532**
IWO	1.852	0.4705	0.10	0.1	0.1892	0.122	767.6021	2.009206
SCE	1.972	0.4687	0.10	0.1	0.1912	0.12	767.6021	22.700301

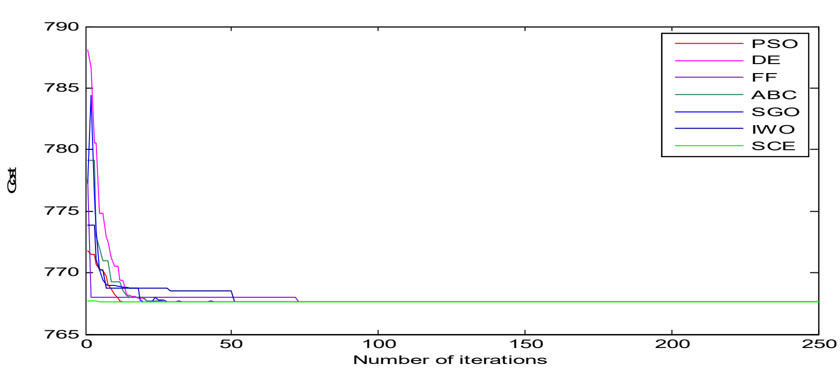

Figure1: Cost curve comparison of test system-1

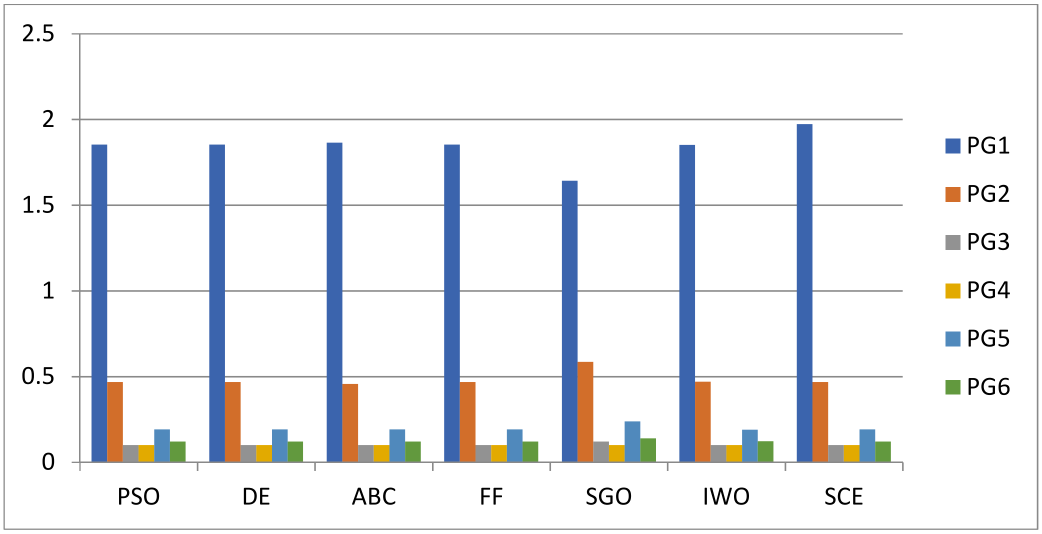

Figure2: Power comparison of test system-1

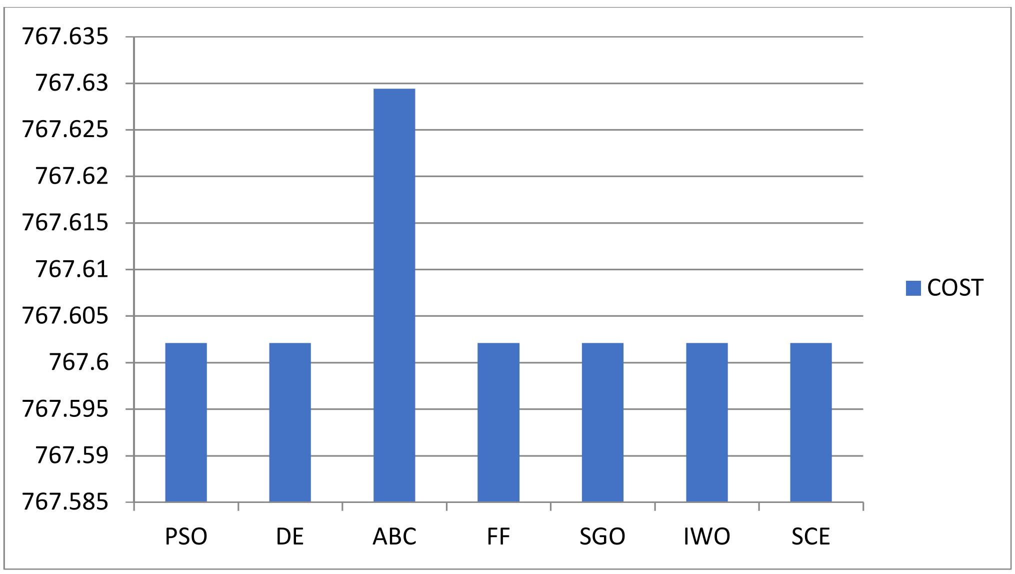

Figure 3: Cost comparison of test system-1

Table 3: Case 2: Data for 7 unit system

Generator Number	a	b	c	Pg_{min}	Pg_{max}
1	775.7595	2000	0	0.0	5.7588
2	100	4000	0	0.0	1.0000
3	2500	2000	0	0.0	1.4000
4	222.22	2000	0	0.0	5.5000
5	100	4000	0	0.0	1.0000
6	100	4000	0	0.0	1.0000
7	322.581	2000	0	0.0	4.1000

Table 4: Results for Case 2: 7 unit system

Technique	P-G1	P-G2	P-G3	P-G4	P-G5	P-G6	P-G7	COST	Time for Execution
PSO	1.3944	0.8173	0.4327	4.8678	0.8173	0.8173	3.3533	40973.000	0.986862
DE	1.3944	0.8173	0.4327	4.8678	0.8173	0.8173	3.3533	40973.000	1.421154
ABC	1.4025	0.8625	0.4349	4.8936	0.7589	0.7917	3.3560	40973.700	1.410569
FF	1.3936	1.0000	0.4114	4.9406	0.6967	0.7485	3.3093	**40981.559**	**5.531228**
SGO	0.9323	0.8560	0.4509	5.0727	0.856	0.856	3.4762	**40973.448**	**1.775215**
IWO	1.3906	0.8177	0.4338	4.8697	0.8197	0.8166	3.3519	40973.357	4.912383
SCE	1.3944	0.8173	0.4327	4.8678	0.8173	0.8173	3.3533	40973.000	20.20598

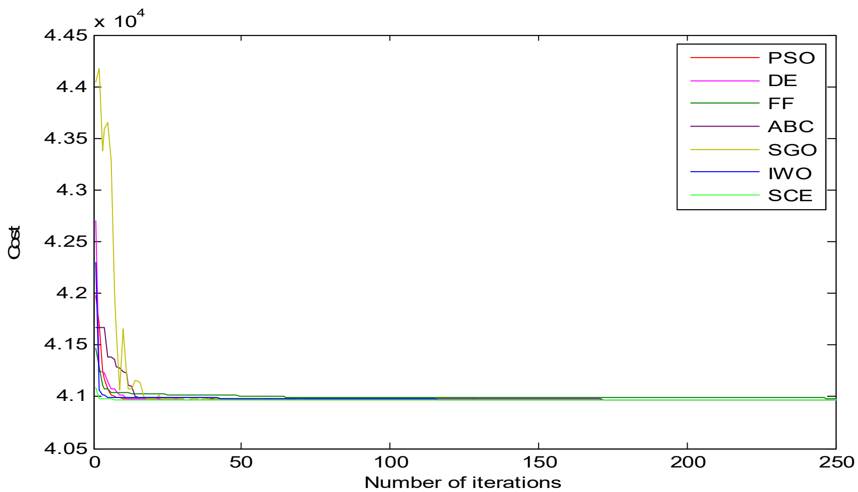

Figure 4: Cost curve comparison of test system-2

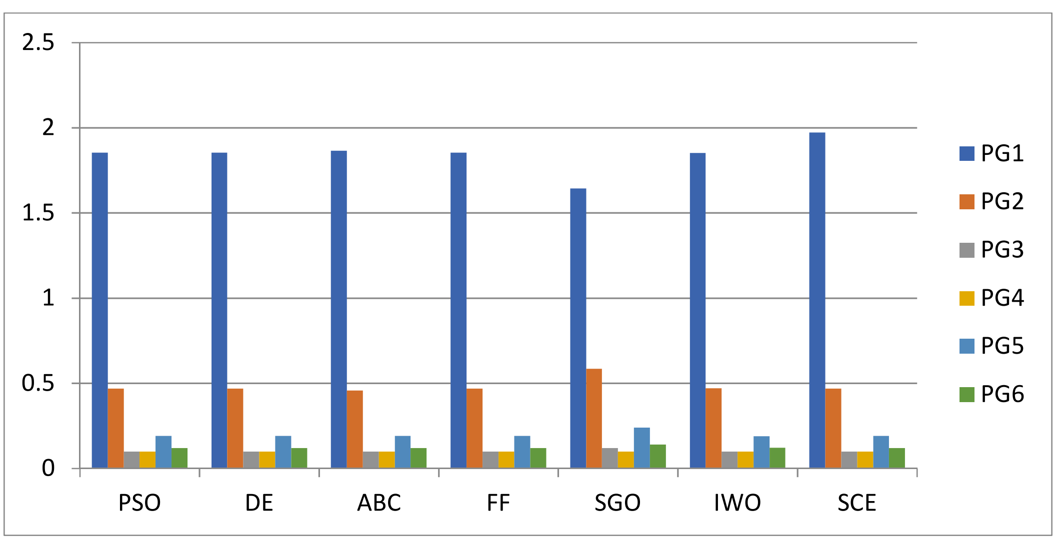

Figure 5: Power comparison of test system-2

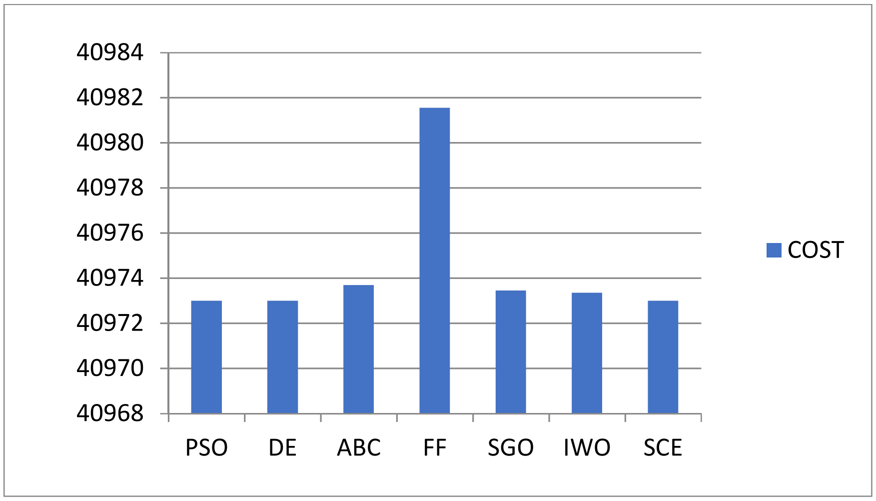

Figure 6: cost comparison of test system-2

Table 5: Case 3: Data for 10 unit system

Generator Number	a	b	c	Pg_{min}	Pg_{max}
1	53.300	213.1	1166.9	1.5	8.9
2	88.900	200.0	1033.3	2.0	7.0
3	74.100	240.0	1083.3	3.0	5.5
4	53.300	213.1	1166.9	1.5	3.0
5	88.900	200.0	1033.3	2.0	4.5
6	74.100	240.0	1083.3	1.0	2.0
7	53.300	213.1	1166.9	1.0	1.5
8	88.900	200.0	1033.3	2.0	3.0
9	74.100	240.0	1083.3	1.5	2.5
10	74.100	240.0	1083.3	6.0	11.0

Table 6. Results for Case 3: 10 unit system

Technique	$P\text{-}G_1$	$P\text{-}G_2$	$P\text{-}G_3$	$P\text{-}G_4$	$P\text{-}G_5$	$P\text{-}G_6$	$P\text{-}G_7$	$P\text{-}G_8$	$P\text{-}G_9$	$P\text{-}G_{10}$	COST	Time for Execution
PSO	6.445	7.000	5.500	3.000	4.500	2.000	1.5	3.00	2.50	6.0	836.25	0.977
DE	6.445	7.000	5.500	3.000	4.500	2.000	1.5	3.00	2.50	6.0	836.25	2.144
ABC	7.696	6.700	4.483	2.967	4.336	1.935	1.5	2.97	1.98	6.8	836.25	2.607
FF	8.900	3.869	3.888	3.000	4.500	2.000	1.5	3.00	2.50	6.3	**831.81**	**6.574**
SGO	6.445	7.000	5.500	3.000	4.500	2.000	1.5	3.00	2.50	6.0	**836.25**	**2.163**
IWO	6.448	7.000	5.498	3.000	4.498	2.000	1.5	3.00	2.49	6.0	836.25	6.098
SCE	8.900	2.838	3.838	3.000	2.838	2.000	1.5	3.00	2.50	6.8	**826.25**	**233.06**

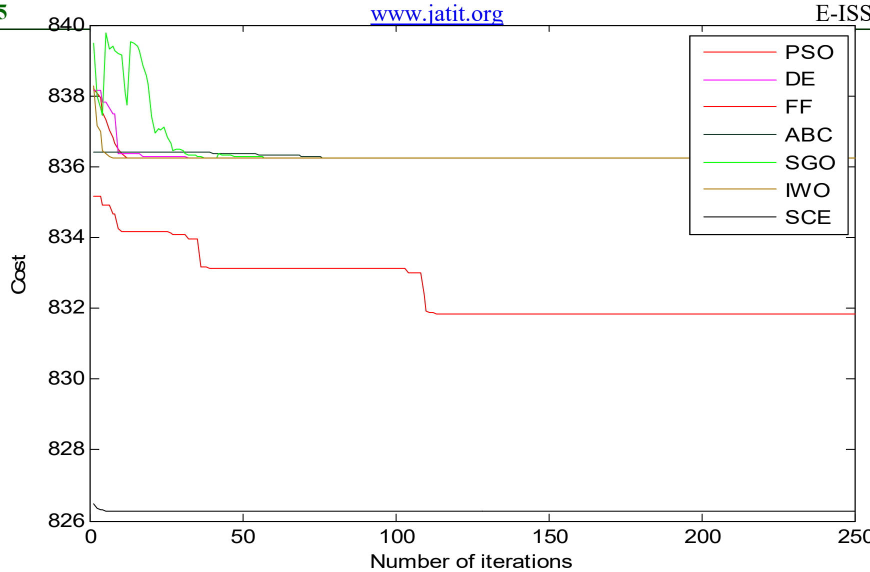

Figure 7: Cost curve comparison of test system-3

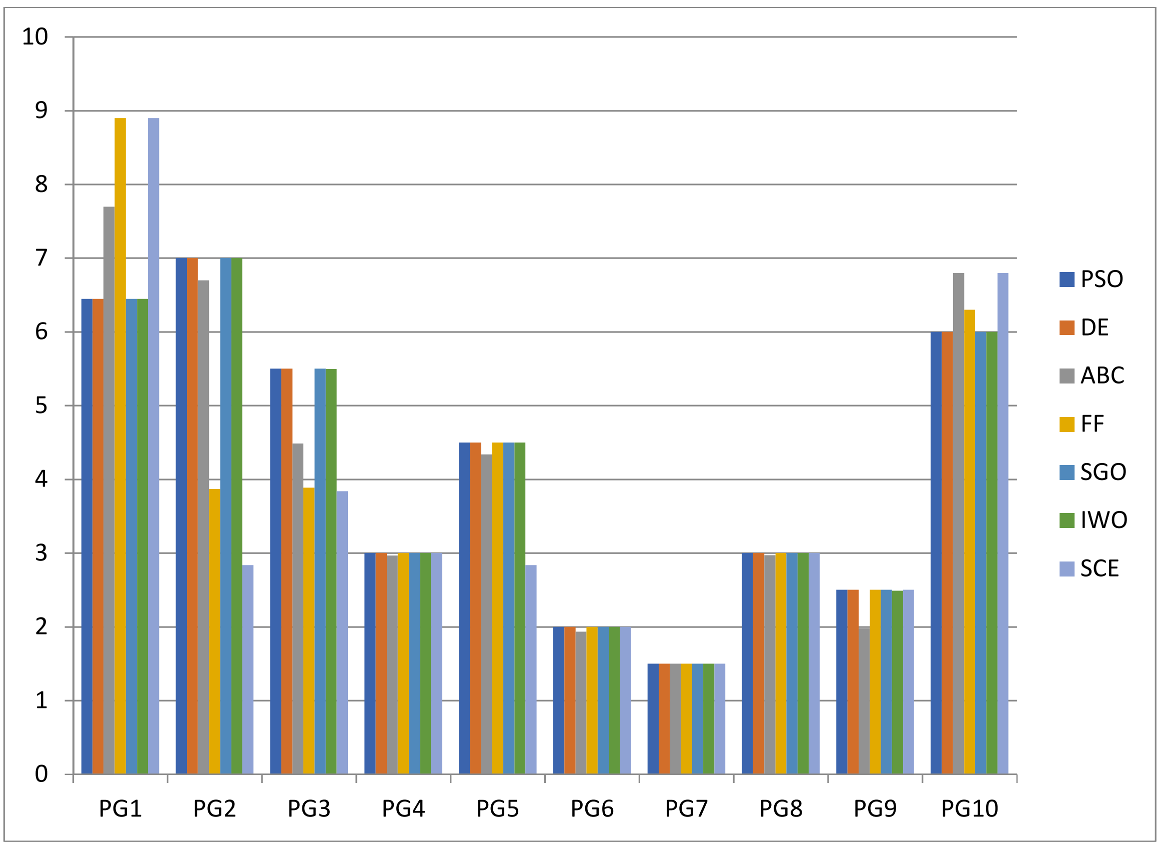

Figure 8: Power comparison of test system-3

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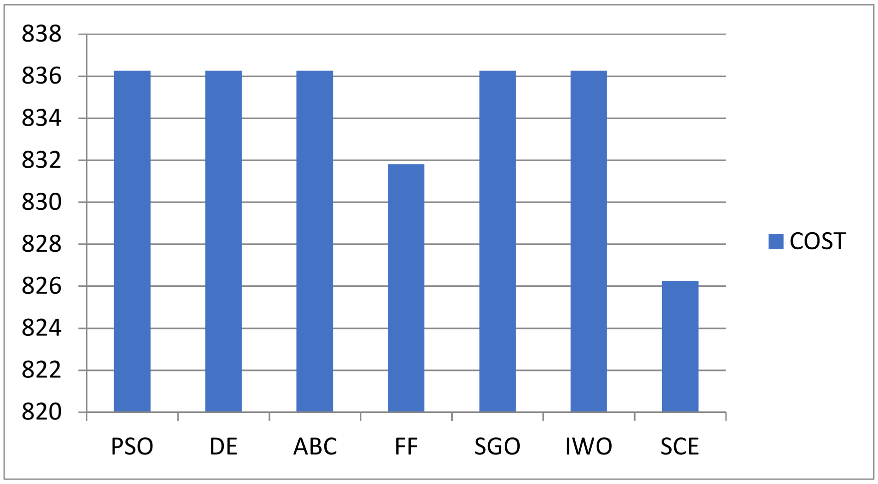

Figure 9: Cost comparison of test system-3

Every algorithm has its own set of benefits and drawbacks, such as the fact that one algorithm lowers the cost of production while another loads the units uniformly and takes less time to execute. By observing the loading of all the generating units, cost of generation, and the execution time for the three cases with different approaches, S.G.O. offers more benefits in terms of the above. The minimum price obtained for a ten generator system is 836.25 $/hr and the execution time is 2.163secs. But the F.F. and S.C.E., the minimum cost obtained is 831.81$/hr and 826.25$/hr, which is less when compared to the other, but the execution time taken by the above approaches is more, i.e., 6.574secs and 233.06secs respectively. Along with the economic benefits, we should see the uniform loading of units achieved with the S.G.O. The corresponding loading and minimum cost obtained are shown below figures.

6. ANALYSIS

With analysis of obtained results, it can be concluded that the S.G.O. approach has a minimum cost compared to the F.F. It takes more time to execute, and the generators are not loaded uniformly. For a seven generator system, the minimum cost obtained is 40973.448$/hr, and the execution time is 1.775215secs with the S.G.O. compared to F.F. the minimum cost obtained is 5.531228 secs.

Even though the cost obtained is the same for small-size systems, the time taken for execution is more for the F.F. approach. 40981.559$/hr and the execution time is 5.531228secs. For a 6 generator system, the minimum price received is 767.6021$/hr, and the execution time is 1.360532secs with the S.G.O. when compared to F.F. the minimum cost obtained is 767.6021$/hr, and the execution time is 5.531228secs.

7. CONCLUSION

This paper applies different soft computing techniques for ELD. Comparative study of various soft computing techniques is done with the help of 3 test cases. From the comparable results from the loading point of view, we can say that the Social group optimization technique is more beneficial when compared with others in obtaining the minimum cost and distributing the power to all the generating units uniformly with the least time taken for execution.

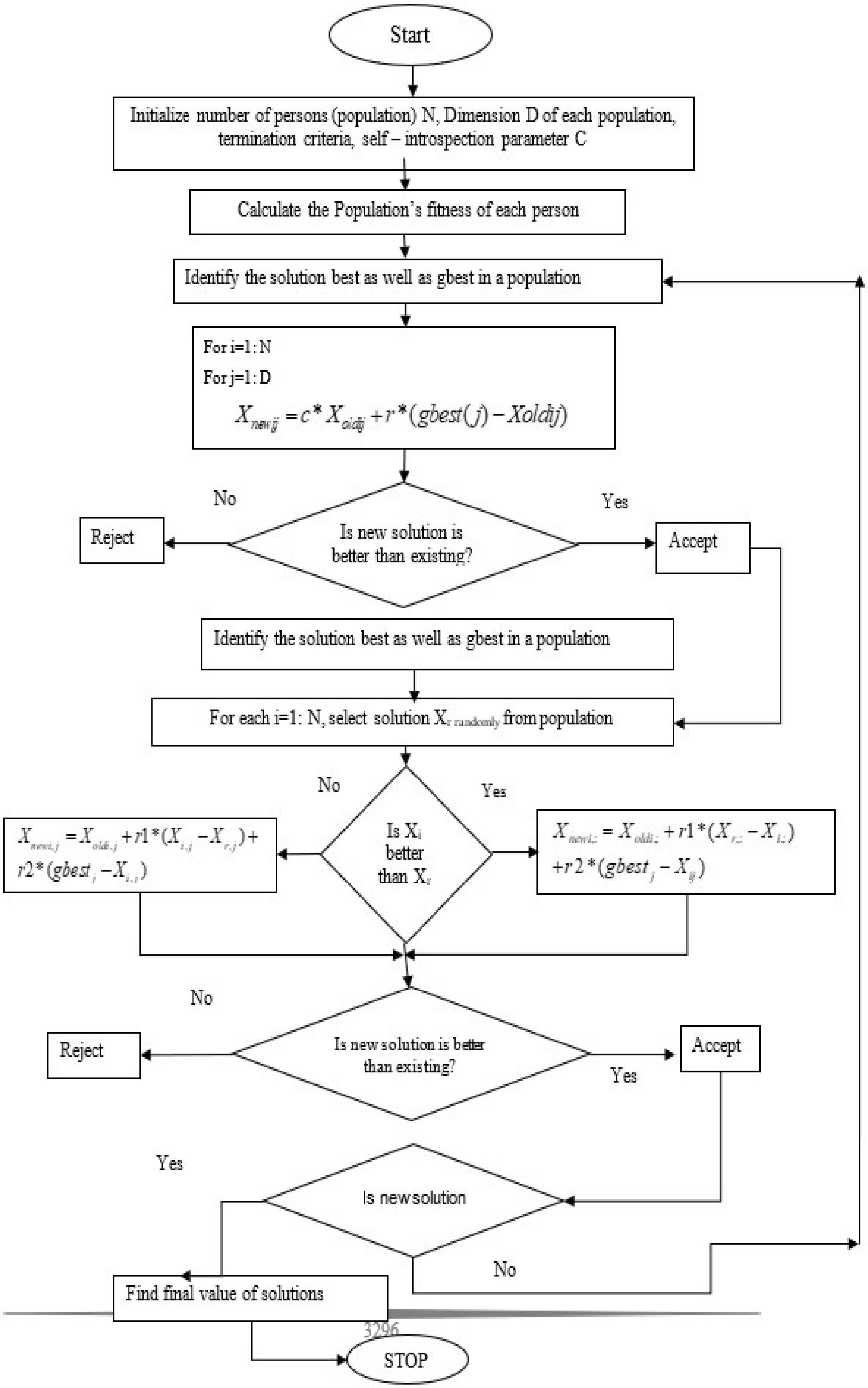

Figure 10: Flowchart of S.G.O. [19,24]

The problem of conventional ELD provided a unique quadratic function that reduces the cost of fuel utilized for a generation—many optimized techniques found in the literature review provided good results. The proposed social group optimization in this paper, in comparison with other methods in the Literature, offers better results. The use of the IWO technique and SGO shows the superiority of the proposed technique with minor time delay. Further, using the proposed SGO, the problem associated with ELD was reduced precisely.

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