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OPTIMAL POWER FLOW PROBLEM SOLUTION USING DIVERSE SOFT COMPUTING TECHNIQUES

VEMULAPALLI HARIKA [1], HEMALATHA JAVVAJI[2], GUDAVALLI MADHAVI [3], MOHAMMED AZAHARAHMED[4], G.VEERANNA[5], MAJAHAR HUSSAIN MAHAMMAD[6]

[1, 3] Assistant Professor, Department of E.E.E., PVP Siddhartha Institute of Technology, India
[2] Sr. Assistant Professor, Department of E.E.E., PVP Siddhartha Institute of Technology, India
[4,5]Assistant Professor, Department of E.E.E., Sagi Rama Krishnam Raju Engineering College, India
[6]Lecturer, Department of E.E.E., King Khalid University,Abha, Saudi Arabia

[1]vemulapalliharika2312@gmail.com , [2]hemajavvaji @gmail.com , [3]gudavalli.madhavi @gmail.com , [4]azahar.yusuf@srkrec.edu.in , [5]veerueee@gmail.com, [6]mhmohamad@kku.edu.sa

ABSTRACT

In attempting to discourse the optimal power flow (OPF) problem, various effective and trustworthy evolutionary-based methodologies are laid out in this article. The suggested methods make use of several algorithms to configure OPF issue control variables optimally. The constraints put on the optimized objective functions are greatly reduced when the social group optimization (SGO) technique is used to solve the OPF problem. The anticipated method has been investigated and tested on the industry-standard IEEE 30-bus test system and IEEE 57 bus test system with a variety of goals in mind, including reducing fuel costs. Results from the suggested strategy have been contrasted with those from other optimization methods. The results are encouraging and demonstrate the resilience and efficacy of the suggested strategy.

Keywords: *Optimal Power Flow(OPF), Differential Evolution(DE), Artificial Bee Colony Algorithm(ABC), Particle Swarm Optimization(PSO), Firefly Algorithm(FF), Social Group Optimization(SGO).*

1. INTRODUCTION

The issue of OPF has drawn a lot of attention over the last two decades. It has been identified as one of the most operational demands and is currently of interest to numerous utilities. The premise of the OPF issue solution is to meet multiple equality and inequality requirements while simultaneously optimizing a defined objective function, such as fuel cost, by making the best adjustments to the power system control variables. The restrictions on control variables and the operating limits of power system dependent variables are examples of inequality constraints, whereas the power flow equations are examples of equality constraints. The problem control variables and problem dependent variables are elaborated briefly here. From these voltages of load bus, reactive powers of generator, and the power flow in lines are termed as problem dependent variables and real powers of generator, bus voltages of generator, tap settings of transformer, power of switchable VAR sources termed as problem control variables. The OPF issues is typically described with consideration of nonlinear, severely constrained, non-convex optimization problem. Many optimization approaches, including sequential unconstrained minimization, Newton-based linear programming, quadratic programming, nonlinear programming, and interior point methods, have been used to solve OPF problems [2-4, 6]. In general, nonlinear programming-based methods have a lot of shortcomings, like unstable convergence characteristics and algorithmic complexity. The piecewise quadratic cost approximation has some drawbacks for strategies based on quadratic programming. The downside of Newton-based approaches is that their convergence characteristics are sensitive to the initial conditions; under the wrong initial conditions, they may even fail to converge. When the penalty factors rise to exceptionally high levels, sequential unconstrained minimization strategies are known to display numerical issues. Despite being quick and dependable, linear programming techniques have several drawbacks that are related to the piecewise linear cost approximation. Although interior point approaches are said to be computationally efficient, the sub-linear issue may have a solution that is impractical in the original nonlinear domain if the step size is not properly set. Furthermore, interior point approaches frequently fail to satisfy the starting, termination, and optimality criteria and frequently struggle to solve nonlinear and quadratic objective functions.

Recent suggestions for heuristic algorithms to solve the OPF problem include genetic algorithms (GA) and evolutionary programming. The stated findings held promise and provided motivation for more research in this area. Sadly, recent study has found that GA performance has some flaws. [7]

The previous researchers tried to minimize the generation cost by utilizing various optimization techniques. In that few of the techniques are bit difficult and there are more parameters that need to adjust but in case of SGO implementation there are only few parameters to adjust, the time taken for the execution irrespective of number of generators is less and the generation cost is minimized with respect to the other techniques.

In this study, a brand-new strategy based on social group optimization is suggested to address the OPF issue. The issue is presented as a mildly constrained test systems, the anticipated technique is reviewed and tested. The effectiveness of the suggested technique is shown in the following sections. The outcomes are also contrasted with those of other optimization methods.

2. MATHEMATICAL FORMULATION

The target of OPF is to lower the overall cost of power generation, which is expressed as

$$\min f(x) = \sum_{i=1}^{NOG} (a_i P_i^2 + b_i P_i + c_i) \qquad (1)$$

Where
f(x) is the overall cost of power generation;
NOG is the number of generators
ai ,bi and ci are the cost coefficients.
f(x) is subjects to equality and in-equality constraints

$$P_i = P_D + P_{loss}$$

$$P_i^{\min} \le P_i \le P_i^{\max}, i = 1,2,......ng$$

$$Q_i^{\min} \le Q_i \le Q_i^{\max}, i = 1,2,......ng$$

$$V_i^{\min} \le V_i \le V_i^{\max}, i = 1,2,......ng$$

$$V_{li}^{\min} \le V_{li} \le V_{li}^{\max}, li = 1,2,......nl$$

Various conventional methods and optimization techniques were implemented by researchers but those are lagging in speed of execution and more parameters to adjust and there is a chance of trapping in local minima for few of the techniques. To overcome the problems and to achieve the minimization of generation cost SGO is developed.

3. PROPOSED ALGORITHM- SOCIAL GROUP OPTIMIZATION

Several innate human behaviors, just like integrity, duplicity, empathy, bravery, terror, and righteousness need to be awakened and directed in the right way in order for a person to be able to handle challenging situations in life. Few people may possess the amount of all these behavioral characteristics necessary to be able to solve complicated challenges in life successfully and efficiently. Yet, dense issues are frequently resolute by the transmission of features from solitary person to alternative or from one societal group to another. Humans have been found to be excellent imitators or followers when it comes to completing tasks. Exploiting group problem-solving skills has proven to be more successful than solo skills. Based on this a new algorithm is proposed that is called as social group optimization technique.

There are two phases in solving the problem, one is improving phase in which the human being try to improve the knowledge to solve the problem by comparing with the person who is having more knowledge of same group in solving the problems and the other is the acquiring phase where the human try to acquire the knowledge by interacting with the person who is having more knowledge in the same group and with the other groups also [12-14].

The proposed method turns out to be quite easy to use and put into practice. SGO is anticipated to enhance the population-based category of successful and profitable optimization approaches, providing researchers with a wide range of alternatives for use in their particular applications. The implementation of the problem with SGO gives us minimum cost of generation when compared with the other methods.

4. RESULTS AND DISCUSSIONS

The proposed optimization techniques are applied on two test systems. The test system considered for minimizing the operating cost of thermal power generators and cost coefficients corresponding to the six and seven generators are given in the below table. Test system one consists 30 buses and 37 transmission lines with two fixed shunts. The goal in this paper is to cut the cost of generation. While meeting the equality and in-equality constraints. Various optimization techniques like PSO [9], DE [1, 5, and 8], ABC [10], and FF [11] are used to compare the effectiveness of the proposed algorithm i.e. social group optimization algorithm. The outcomes spectacle the efficacy of the anticipated method. The minimum cost, the power loss and the amount of power generation for the considered test case with different algorithms is shown in figure below. The minimum cost obtained with the social group optimization is 802.21($/hr.) The power loss obtained is 8.73MW.The voltages of all the six generators are within the boundaries. The generation of all the six generators is given in the bar graph.

Test system two consists of 57 buses and 80 transmission lines with three fixed shunts. The minimum cost obtained with the social group optimization is 40973.41($/hr.) The power loss obtained is 23.41 MW. The voltages of all the seven generators are within the limits. The generation of all the seven generators is given in the bar graph. The power loss and the minimum generation cost of both the test systems are related with the other optimization techniques like PSO, DE, ABC and FF. The results obtained are of encouraging and shows the efficacy of the proposed SGO.

Table 1. Data for Case 1: 6 unit system

Generator	a_i	b_i	c_i
1	37.5	200	0
2	175	175	0
3	83.4	325	0
4	250	300	0
5	625	100	0
6	250	300	0

System	IEEE 30
Number of buses	30
Number of lines	47
Number of generators	6
Number of shunts	2

Table 2. Optimum values for Case 1: 6 unit system

Variable Names	Min	Max	PSO	DE	ABC	FF	SGO
PG1(MW)	50	200	174.8860	155.9670	174.9148	170.9840	175.00
PG2(MW)	20	80	48.3614	67.8898	48.3099	46.5991	48.2894
PG3(MW)	10	35	24.6884	33.8778	24.7060	32.1865	24.6783
PG4(MW)	10	30	12.0449	10.7865	12.0526	10.0000	11.9190
PG5(MW)	15	50	20.7078	40.5589	20.7049	19.2032	20.8080
PG6(MW)	12.0	39	12	12	12	13.2337	12
Per unit V_1	0.95	1.05	1.060	1.060	1.060	1.060	1.060
Per unit V_2	0.95	1.05	1.043	1.043	1.043	1.043	1.043
Per unit V_3	0.95	1.05	1.010	1.010	1.010	1.010	1.010
Per unit V_4	0.95	1.05	1.010	1.010	1.010	1.010	1.010
Per unit V_5	0.95	1.05	1.082	1.082	1.082	1.082	1.082
Per unit V_6	0.95	1.05	1.071	1.071	1.071	1.071	1.071
Fuel cost($/hr)	--	--	802.21	802.80	802.21	803.22	**802.21**
Power Loss(MW)	--	--	9.28	6.50	9.28	8.80	**8.73**

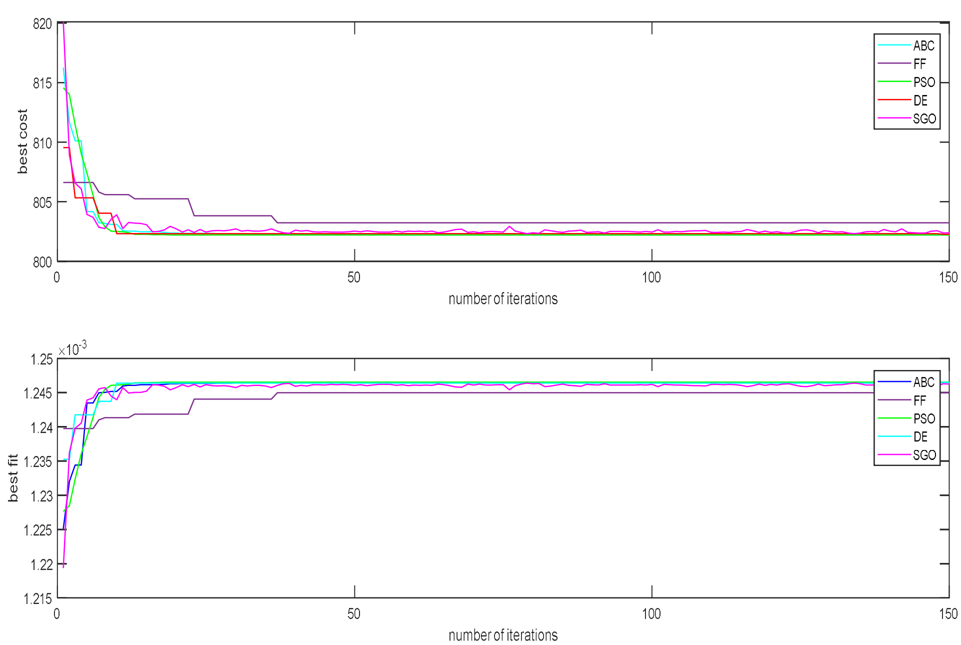

Figure1: Optimized cost and fitness curves for test system-1

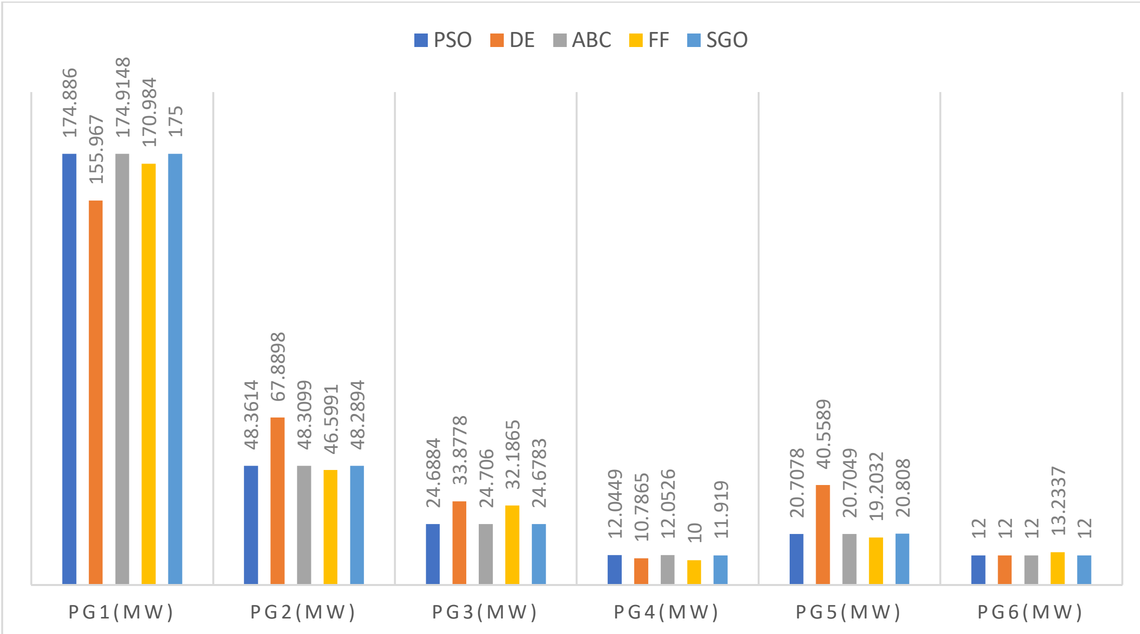

Figure2: Test system-1 power comparison

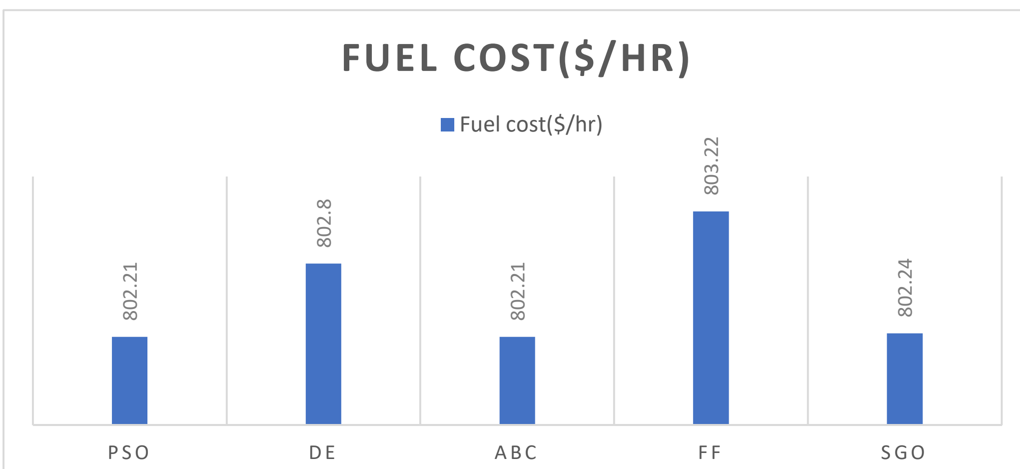

Figure 3: Test system-1 cost comparison

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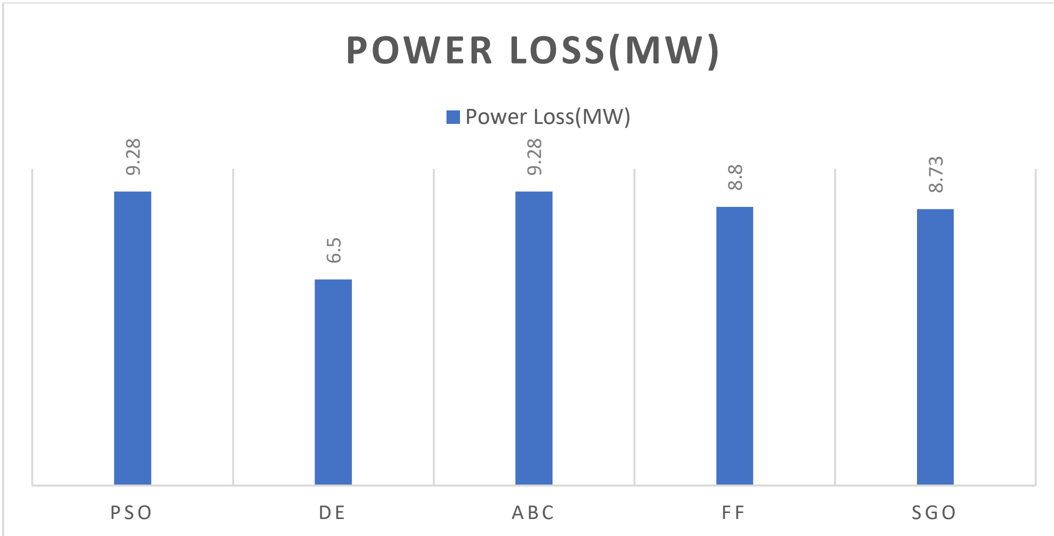

Figure 4: Test system-1 power loss comparison

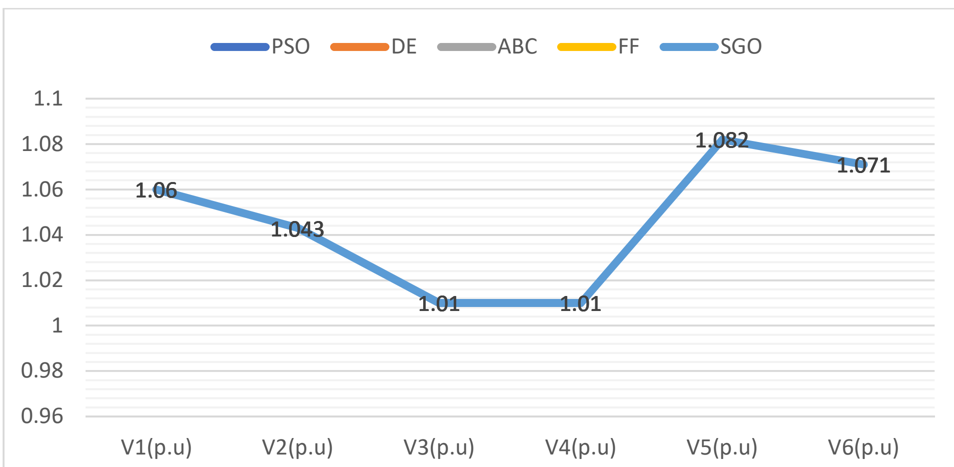

Figure 5: Voltages of test system-1

Table 3: Case 2: Data for 7 unit system

Generator	a_i	b_i	c_i
1	775.7595	2000	0
2	100	4000	0
3	2500	2000	0
4	222.222	2000	0
5	100	4000	0
6	100	4000	0
7	322.581	2000	0

System	IEEE 57
Number of buses	57
Number of lines	80
Number of generators	7
Number of shunts	3

Table 4. Optimum values for Case 2: 7 unit system

Variable Names	Min	Max	PSO	DE	ABC	FF	SGO
PG1(MW)	0	575.88	144.83	144.83	143.01	135.68	116.61
PG2(MW)	0	100	92.84	92.84	92.67	100.00	85.45
PG3(MW)	0	140	45.20	45.20	45.71	42.47	45.08
PG4(MW)	0	550	456.95	456.99	450.98	459.61	507.20
PG5(MW)	0	100	95.65	95.65	97.85	98.70	85.52
PG6(MW)	0	100	68.18	68.14	77.85	74.35	85.47
PG7(MW)	0	410	365.76	365.75	361.44	359.24	348.03
Per unit V_1	0.95	1.05	1.04	1.04	1.04	1.04	1.04
Per unit V_2	0.95	1.05	1.01	1.01	1.01	1.01	1.01
Per unit V_3	0.95	1.05	0.99	0.99	0.99	0.99	0.99
Per unit V_4	0.95	1.05	1.01	1.01	1.01	1.01	1.01
Per unit V_5	0.95	1.05	0.98	0.98	0.98	0.98	0.98
Per unit V_6	0.95	1.05	0.98	0.98	0.98	0.98	0.98
Per unit V_1	0.95	1.05	1.02	1.02	1.02	1.02	1.02
Fuel cost($/hr)	--	--	41839.10	41839.11	41839.50	41853.45	**40973.40**
Power Loss(MW)	--	--	19.39	19.41	19.51	20.05	23.41

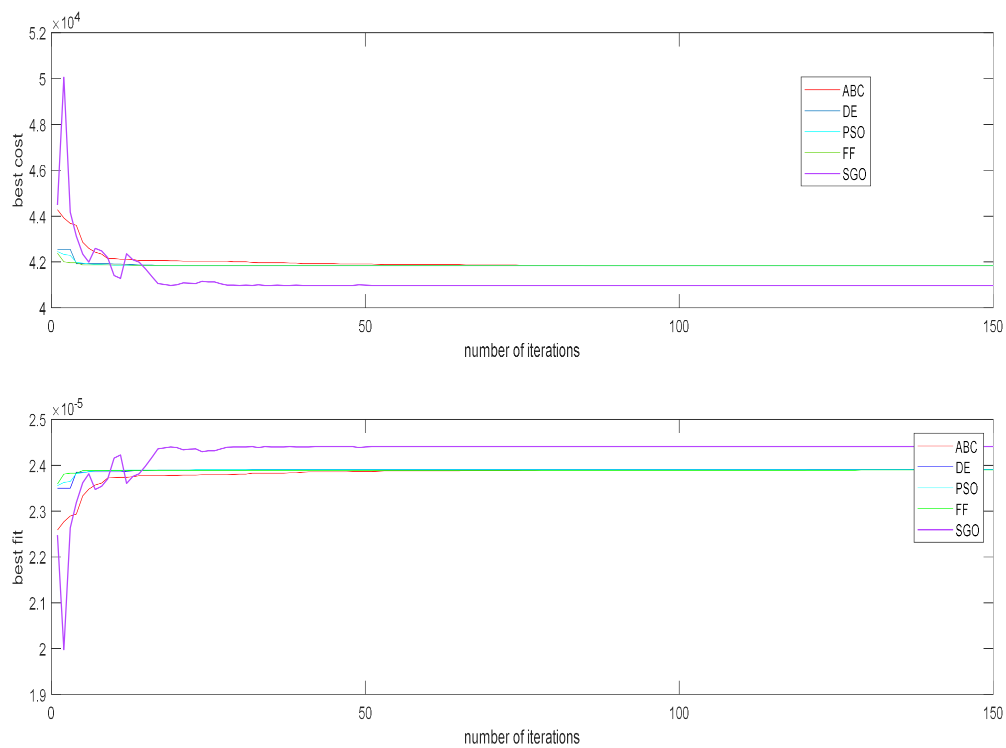

Figure 6: Optimized cost and fitness curves for test system-1

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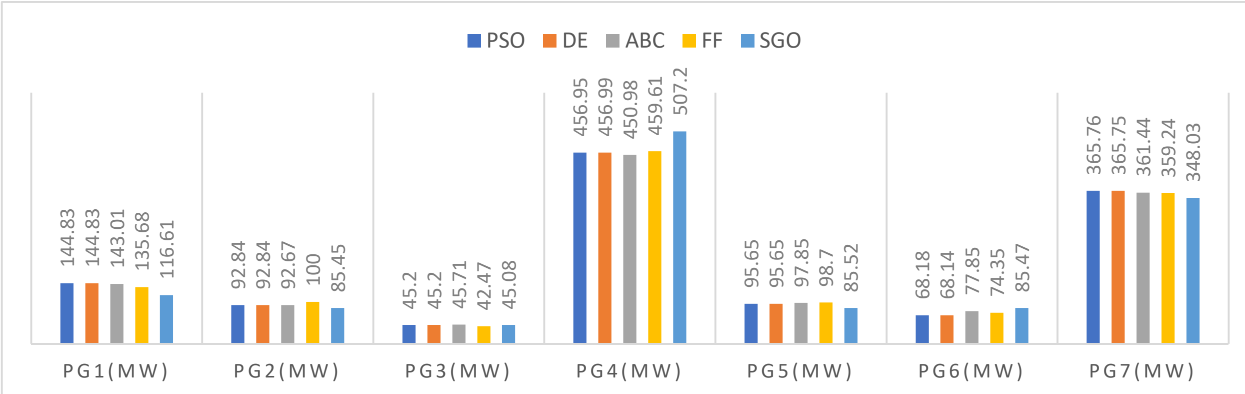


Figure 7: Test system-2 Power comparison

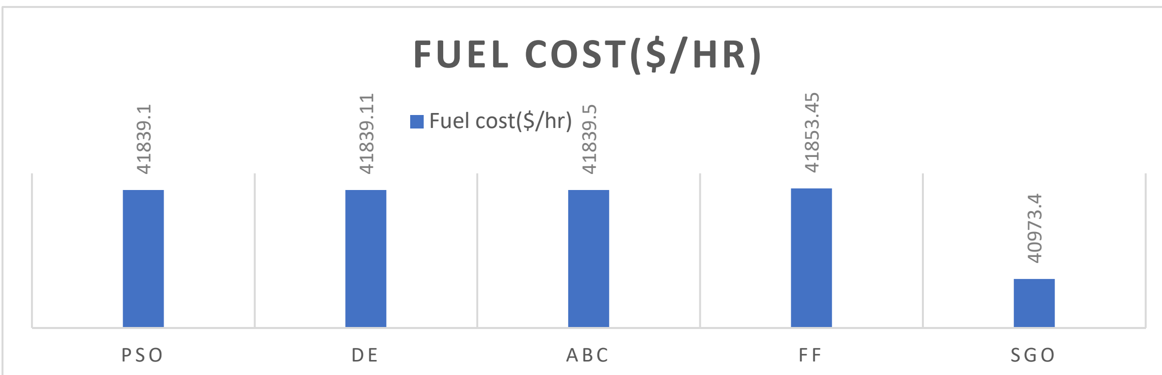


Figure 8: Test system-2 cost comparison

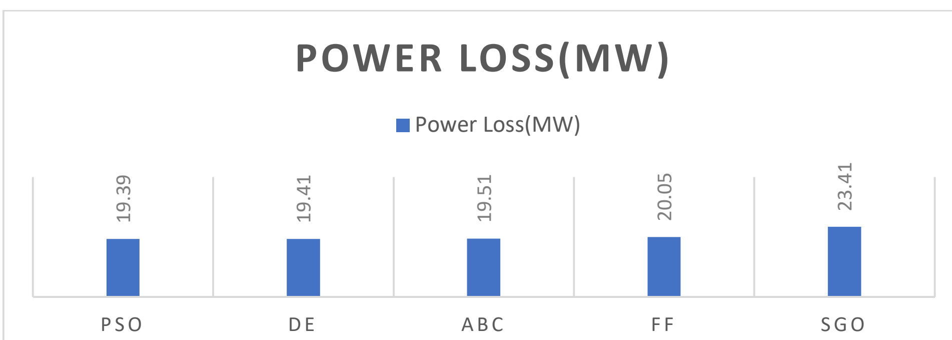


Figure 9: Test system-2 Loss comparison

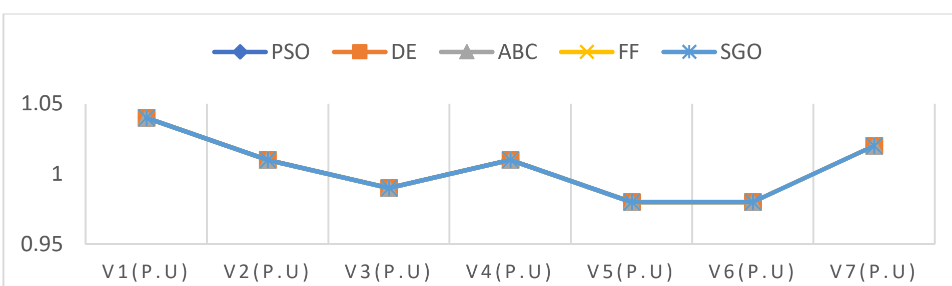
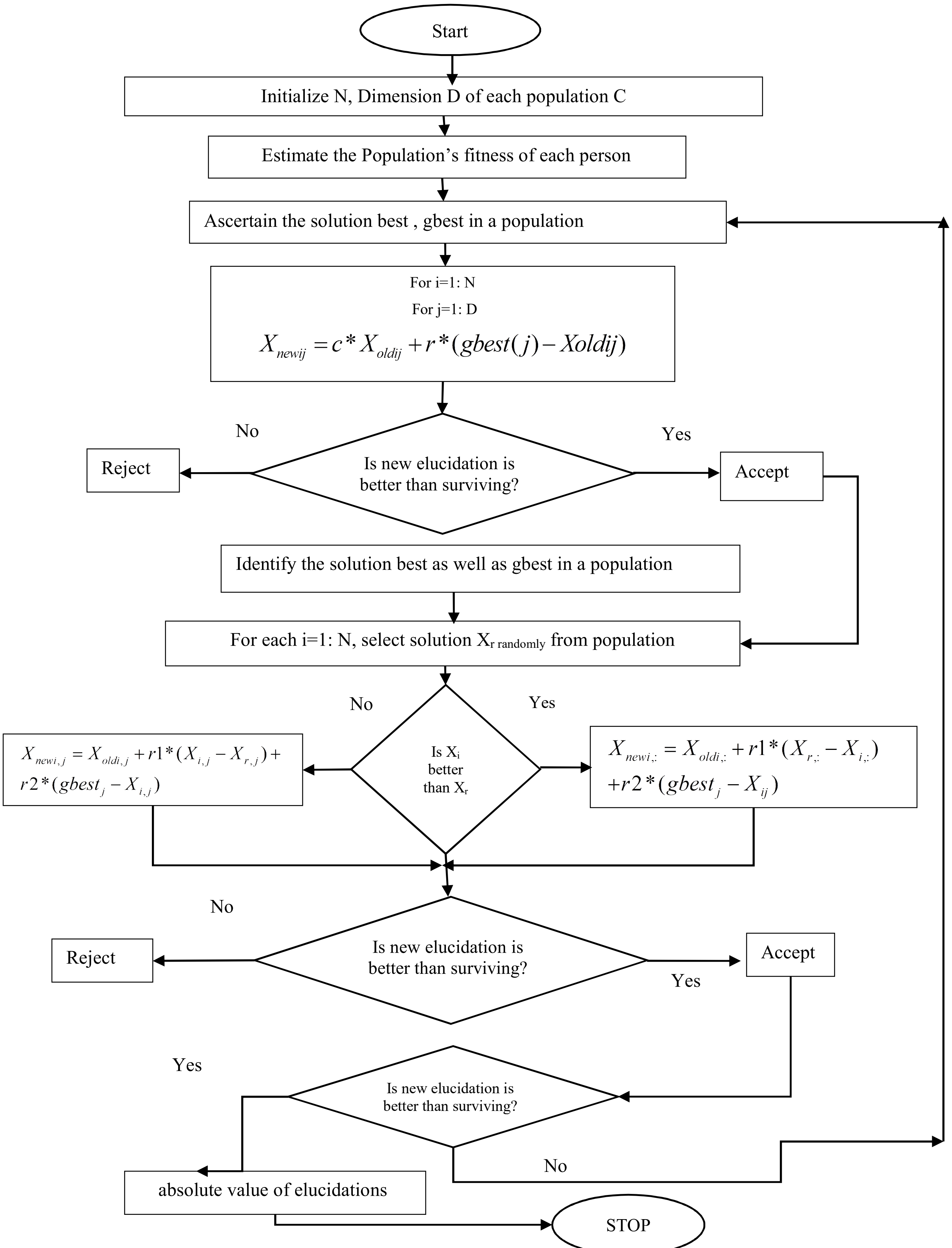


Figure 10: Voltages of test system-2


Start
Initialize N, Dimension D of each population C
Estimate the Population's fitness of each person
Ascertain the solution best , gbest in a population
For i=1: N
For j=1: D
$X_{newij} = c * X_{oldij} + r * (gbest(j) - Xoldij)$
No
Yes
Reject
Is new elucidation is better than surviving?
Accept
Identify the solution best as well as gbest in a population
For each i=1: N, select solution $X_{r\ randomly}$ from population
No
Yes
$X_{newi,j} = X_{oldi,j} + r1 * (X_{i,j} - X_{r,j}) + r2 * (gbest_j - X_{i,j})$
Is X_i better than X_r
$X_{newi,:} = X_{oldi,:} + r1 * (X_{r,:} - X_{i,:}) + r2 * (gbest_j - X_{ij})$
No
Reject
Is new elucidation is better than surviving?
Accept
Yes
Yes
Is new elucidation is better than surviving?
No
absolute value of elucidations
STOP

Each algorithm has its own pros and cons, such as the fact that one method decreases production costs while another uniformly loads the units and runs faster. S.G.O. provides more advantages in terms of the aforementioned.

5. CONCLUSION

The optimal flow problem is solved in this work using a social group optimization approach. The suggested technique is effective in finding the feasible global optimum because it moves towards the feasible area. On the IEEE-30 and IEEE-57 buses, the anticipated algorithm's efficacy is tested. When compared to advanced algorithms, the proposed method's act is competitive in terms of convergence speed and precision.

The suggested techniques may one day be applied to more challenging optimal flow issues. This algorithm could be used with more efficient constraint management methods to handle challenging constrained optimization issues. This paper focused on only one objective i.e. minimization of generation cost. In the future it may extend to multi objective functions.

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