

Grasshopper Optimization Algorithm For Optimizing Microgrid Networks To Achieve Economic Dispatch

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Abstract—In recent years, energy management has become an essential issue in the growing integration of microgrids, enabling more efficient and sustainable energy use. This research focuses on optimizing microgrid networks to achieve economic dispatch using the Grasshopper Optimization Algorithm (GOA). Economic dispatch aims to minimize total generation costs while meeting load demand. Traditional methods such as Particle Swarm Optimization (PSO), Priority List (Merit Order), and the Lagrange method have been widely used. Still, GOA offers superior performance potential in cost efficiency and computational effectiveness. This study compares the efficacy of PSO, GOA, Priority List, and the Lagrange method in optimizing microgrid operations through a series of simulations. Key performance metrics include total generation costs, convergence rates, and computation time. The results showed that GOA was superior to PSO and Priority List in reducing generation costs, with differences of \$3.8 per hour of generation compared to PSO and \$39.8 per hour of generation compared to Priority List. Additionally, GOA has a more adaptive convergence rate. However, the Lagrangian method does not apply to all objective functions, making it less effective for solving economic dispatch problems. In conclusion, GOA could significantly improve the economic efficiency of microgrid systems, contributing to more sustainable and cost-effective energy management. The combination of various optimization methods, such as GOA, PSO, and others, offers a more comprehensive approach to facing future energy management challenges.

Index Terms— Energy management; Economic Dispatch; GOA; Lagrange; Microgrid; Priority List; PSO

Abstrak—Dalam beberapa tahun terakhir, manajemen energi telah menjadi isu penting dalam meningkatkan integrasi mikrogrid, yang memungkinkan penggunaan energi yang lebih efisien dan berkelanjutan. Penelitian ini berfokus pada optimasi jaringan mikrogrid untuk mencapai economic dispatch menggunakan Grasshopper Optimization Algorithm (GOA). Economic dispatch bertujuan untuk meminimalkan total biaya pembangkitan dengan tetap memenuhi kebutuhan beban. Metode tradisional seperti Particle Swarm Optimization (PSO), Priority List (Merit Order), dan metode Lagrange telah banyak digunakan, namun GOA menawarkan potensi kinerja yang lebih unggul dalam efisiensi biaya dan efektivitas komputasi. Studi ini membandingkan efektivitas PSO, GOA, Priority List, dan metode Lagrange dalam mengoptimalkan operasi mikrogrid melalui serangkaian simulasi. Metrik kinerja utama meliputi total biaya pembangkitan, laju konvergensi, dan waktu komputasi. Hasil penelitian menunjukkan bahwa GOA lebih unggul dibandingkan PSO dan Priority List dalam menurunkan biaya pembangkitan, dengan selisih sebesar \$3,8 per jam pembangkitan dibandingkan PSO dan \$39,8 per jam pembangkitan dibandingkan Priority List. Selain itu, GOA memiliki laju konvergensi yang lebih adaptif. Sementara itu, metode Lagrange tidak dapat diterapkan pada semua fungsi objektif, sehingga kurang efektif dalam menemukan solusi untuk economic dispatch. Sebagai kesimpulan, GOA dapat meningkatkan efisiensi ekonomi sistem mikrogrid secara signifikan, sehingga berkontribusi pada manajemen energi yang lebih berkelanjutan dan hemat biaya. Kombinasi berbagai metode optimasi, seperti GOA, PSO, dan lainnya, menawarkan pendekatan yang lebih komprehensif untuk menghadapi tantangan manajemen energi di masa depan.

Kata Kunci— Manajemen energi; Economic dispatch; GOA; Lagrange; Mikrogrid; priority list; PSO.

I. INTRODUCTION

Since the discovery of electricity, it has become an essential aspect of human life. Initially used primarily for lighting, electricity demand has expanded rapidly across sectors, including healthcare, automotive, and small- and large-scale industries. Today, electrical energy is indispensable for facilitating human activities.

The governance of electricity, both in regulation and in use, is crucial because many energy sources, such as those that rely on fossil fuels, are finite and environmentally damaging. Therefore, there is a pressing need to transition to environmentally friendly and sustainable energy sources. Renewable

resources and electrical energy efficiency are pivotal for industrial development and improving living standards [1].

Technological advancements significantly contribute to the rising demand for electricity. This increasing demand cannot be addressed merely by expanding the number of power plants[1], comprehensive feasibility studies are essential before constructing new facilities. Such studies must account for multiple factors to ensure that electricity producers can manage generation efficiently, meet demand, and avoid high operational costs.

Electricity is now a basic necessity for modern society. With the growing world population and advancing industrial activities, accurate and timely planning is crucial. Minimizing operational costs is imperative given the high costs of electricity generation, rapid demand growth, and limited new power-plant installations.

Economic Dispatch (ED) is a critical concept in power systems and energy management. It involves allocating generation levels among various power plants to meet total load demand at the lowest possible cost while adhering to operational constraints. The temperature gradient must be maintained within safe limits, and the rate of change of output power, known as the ramp rate, must be controlled. Traditional ED approaches can handle only a single load level and may cause generators to violate ramp-rate constraints during extended loading periods. This limitation necessitates a more dynamic and adaptable approach to Economic Dispatch that can accommodate varying load levels while ensuring operational efficiency and cost-effectiveness [7].

II. LITERATURE REVIEW

A. Economic Dispatch

Economic Dispatch (ED) is a fundamental problem in power system operations, which involves determining the optimal outputs of multiple generation units to minimize total generation cost while satisfying total demand and operational constraints. The problem has been extensively studied, and various methodologies have been proposed to address its complexities and practical challenges. This review covers the evolution of ED methods, highlighting classical approaches and recent advancements in the field.

Optimization in the economic dispatch problem is performed with respect to production costs, raw materials, or fuel costs. Fuel costs for power plants have non-linear characteristics. The production cost equation in equation [2] is a second-order polynomial and generally takes the following form [3].

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

$$\text{Min } \sum F_i(P_i) = \text{Min } \sum a_i P_i^2 + b_i P_i + c_i$$

$$P_{Gi} \text{ min} \leq P_G \leq P_{Gi} \text{ max}$$

Where :

F_i = generation cost at i – th generation (\$)

P_i = Output power of generating unit i (MW)

P_{Gi} = amount of power generated by the i – th generator

The variables a , b , c are constant operating costs of a generator. The coefficient c represents the generator's operating costs when it is not producing electrical energy. Based on equation (1), the generator's power output is nonlinearly related to generation costs. The combination of output power generated by each generator in the system must meet the power requirements of the electrical energy system (equality constraint) in accordance with equation (2) and meet the minimum and maximum limits of power that can be generated by the generator (inequality constraint) in accordance with equation (3). The equality- and inequality-constraint parameters can be represented by the following equation [3].

B. Classical Approaches to Economic Dispatch

Lambda Iteration Method

The Lambda Iteration Method is one of the earliest and most straightforward approaches to solving the ED problem. It is based on the equal incremental cost criterion, which states that, for optimal dispatch, the incremental cost of all units should be equal [4].

The objective function is to minimize the total fuel cost.

$$\sum_{i=1}^{n_g} P_i = P_D$$

The Lagrangian function approach is given in equation (5).

$$\mathcal{L} = C_t + \lambda \left(P_D - \sum_{i=1}^{n_g} P_i \right)$$

Where :

P_i = Power generated by generator i – th

P_D = Load Demand

n_g = Total Generator

C_t = Total Cost Production

C. Modern Approaches and Algorithms

PSO

(Particle Swarm Optimization) It is an optimization algorithm inspired by the behaviours of groups (swarms) in resource search. This system operates a population of particles that move through a search space and communicate with one another to find an optimal or near-optimal solution to an optimization problem [5].

In the case of Economic Dispatch, the main objective is to determine the optimal power allocation for each power generation unit in the power system by minimizing total production costs while satisfying all technical and operational constraints. PSO can be applied to find the optimal solution to this problem[5].

$$P_{ij}^{(n+1)} = P_{ij}^{(n)} + V_{ij}^{(n+1)}$$

Velocity

$$V_{ij}^{(n+1)} = w * V_{ij}^{(n)} + c_1 * rand_1 * (Pbest_{ij} - P_{ij}^{(n+1)}) + c_2 * rand_2 * (gbest_{ij} - P_{ij}^{(n+1)})$$

Where

V_{ij}^n is velocity matrix in the particle matrix i and $V_j^{(Min)} \leq V_{ij}^n \leq V_j^{(Max)}$

$P_{ij}^{(n)}$ = is the latest Position of Matrix j in the particle Matrix i in the Iteration.

w = Inertia

N = is the number of dimensions of a particle

c_1, c_2 = Constant Speeds in Iterative computing

$Pbest$ = Best Positon in the Iteration

$Gbest$ = Global Best Positon in the Whole Iteration

$rand_1, rand_2$ = Random Value with interval [0 – 1]

GOA

Grasshopper Optimization Algorithm (GOA) is an optimization algorithm inspired by the movement behaviours of grasshoppers in searching for food or shelter. This algorithm belongs to the class of heuristic and metaheuristic optimization algorithms used to find an optimal or near-optimal solution to an optimization problem [6].

$$P_i^d = c \sum_{\substack{j=1 \\ j \neq i}}^N c \frac{ub_d - lb_d}{2} (|P_j^d - P_i^d|) \frac{P_j - P_i}{d_{ij}} + T_d$$

$$c = C_{Max} - t \frac{C_{max} - C_{min}}{T_{max}}$$

where C_{Max} is the maximum value, C_{min} is the minimum value, iteration and max iterations indicate the current iteration and the maximum number of iterations, respectively. The outer c weakens the repulsion and attraction forces between the grasshoppers, with the magnitude of this weakening proportional to the number of iterations. At the same time, the inner c scales down the attraction, comfort, and repulsion zones between the grasshoppers. The factor $c \frac{ub_d - lb_d}{2}$ linearly shrinks the space that the grasshoppers should explore and exploit. The factor $s(|P_j^d - P_i^d|)$ hints whether a grasshopper should be repelled from (i.e., explore) or attracted to (i.e., exploitation) the target[6].

III. METHODOLOGY

Some literature needs to be of concern in this research, namely comparing Classical Methods such as Lambda Iteration or what we usually know as Lagrange which is based on Mathematical calculations with Modern Methods, which are Computerized Based or Computer-based calculations, such as PSO and GOA, as alternative solutions and as the focus of research in Performance comparison in this thesis research[6].

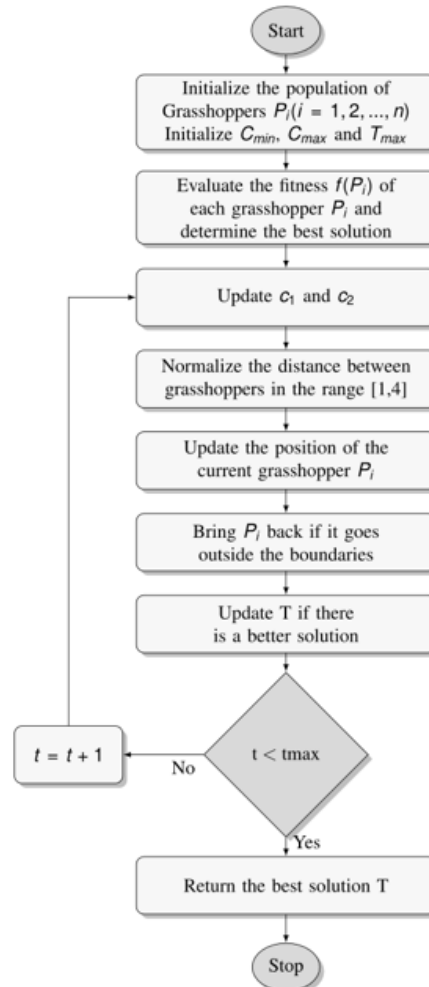


Fig. 1. Grasshopper Flowchart

IV. DATA SIMULATION AND ANALYSIS RESULTS

A. Data Simulation

The data used in this research are technical data on the Microgrid network as the research object, obtained from IEEE journals and ScienceDirect.

In this study, we will conduct a simulation using the following scenario.

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1. Economic dispatch programming simulation with 3 generators using the Lagrange, PSO, and GOA methods
2. Economic dispatch programming simulation with 5 generators using PSO and GOA methods with 10 iterations, population 10
3. Economic dispatch programming simulation with 5 generators using the PSO and GOA methods, with 100 iterations, with a population of 100
4. Economic dispatch programming simulation with 5 generators using the PSO and GOA methods with 500 iterations with a population of 100.

Table 1. Data Typical 3 Generators

Cost Coefficient	Steam Power Plant 1	Steam Power Plant 2	Combine Cycle Power Plant	Solar	Wind
a	561	310	78	0	0
b	7,92	7,85	7,97	0	0
c	0,001562	0,00194	0,00482	0	0
P Max	600	400	200	0	0
P Min	150	100	50	0	0
FLAC	9,7922	9,401	9,324	0	0

Table 2. Data Typical 5 Generators

Cost Coefficient	Steam Power Plant 1	Steam Power Plant 2	Combine Cycle Power Plant	Solar	Wind
a	992	600	1530	0	0
b	20,16	20,4	21	0	0
c	0,029	0,021	0,024	0	0
P Max	100	100	100	2	15
P Min	40	40	25	0,5	2
FLAC	32,98	28,5	38,7	0	0

Table 3. Load Demand Data

No	Time (Hour)	Load (MW)	No	Time (Hour)	Load (MW)
1	1	165	13	13	225
2	2	170	14	14	230
3	3	175	15	15	235
4	4	180	16	16	240
5	5	185	17	17	245
6	6	190	18	18	250
7	7	195	19	19	250
8	8	200	20	20	250
9	9	205	21	21	250
10	10	210	22	22	240
11	11	215	23	23	200
12	12	220	24	24	160

B. Analysis Results

In this chapter, analysis, discussion, and calculations will be carried out to optimize the Economic Dispatch (ED) using three methods: the Lagrangian method, Particle Swarm Optimization (PSO), and the Grasshopper Optimization Algorithm (GOA). The main objective of this chapter is to implement each technique for solving the ED problem and compare their performance in terms of result accuracy and convergence.

1. Results Running Program with 3 Generators
MATLAB Simulation Lagrange Method

```

1 % This program computes the total generation cost. It requires the
2 % real power generation schedule and the cost matrix.
3 % Copyright (C) 1998 by H. Saadat
4
5 % Matriks Cost Coefficients (a,b,c) "Objection Function/Fuel Cost Unit"
6 cost = [561 7.92 0.001562
7         310 7.85 0.00194
8         78 7.97 0.00482
9         ];
10
11 % Upper Limit dan Lower Limits Generator
12
13 limits=[150 600
14         100 400
15         50 200
16         ];
17 % Demand Load Profile
18 Pdt = 850;
19 dispatch
20 gencost
21
22
23

```

Command Window

```

>> Lagrange_Method
Incremental cost of delivered power (system lambda) = 9.148263 $/MWh
Optimal Dispatch of Generation:
393.1698
334.6038
122.2264

Total generation cost = 8194.36 $/h

```

Fig. 2. Output Simulation Lagrange Method

From Figure 2, we see that the MATLAB program has simulated the object function of 3 generators using the Lagrange method, yielding power distributions of 393.1698 MW for the first unit, 334.6038 MW for the second unit, and 122.2264 MW for the third unit.

Additionally, the distribution of power for each generator is consistent with its power constraints, indicating that the simulation for this case was successful and yielded a generation cost of \$ 8194.36/h with a Demand Load of 850 MW.

```

1 % This program computes the total generation cost. It requires the
2 % real power generation schedule and the cost matrix.
3 % Copyright (C) 1998 by H. Saadat
4
5 % Matriks Cost Coefficients (a,b,c) "Objection Function/Fuel Cost Unit"
6 cost = [345 5.92 0.001562
7         325 5.85 0.00194
8         48 3.97 0.00482
9         ];
10
11 % Upper Limit dan Lower Limits Generator
12
13 limits=[150 600
14         100 400
15         50 200
16         ];
17 % Demand Load Profile
18 Pdt = 850;
19 dispatch
20 gencost
21
22
23

```

Command Window

```

>> Lagrange_Method
Incremental cost of delivered power (system lambda) = 6.843864 $/MWh
Optimal Dispatch of Generation:
295.7310
256.1584
298.1186

Total generation cost = 5835.01 $/h

```

Fig. 3. Figure 2 Output Simulation Lagrange Method with modification Objection Function

In Figure 3, we present a MATLAB program that was simulated for 3 power plants, using the Lagrangian method with different objective functions, with a constant demand of 850 MW. This scenario is designed to assess whether the Lagrangian method can be applied to each given objective function. After conducting simulations with different objective functions, the results indicate that the power distribution for the First Unit is 295.7310 MW, for the Second Unit 256.1504 MW, and for the Third Unit 298.1186 MW.

It can be concluded from Figure 3 that the Lagrange method is not in accordance with the constraints of the capacity of each generator for the third power plant, which received a capacity of 298.1186 MW, even though, according to the typical data provided, the capacity of the third power plant is only between 50 and 200 MW. This indicates that the simulation program is overcapacity, and it can be concluded that the simulation program for the different Objection Function cases was not successful.

The Lagrangian method cannot be used to optimize load distribution on the grid; therefore, it cannot be used to solve the Economic Dispatch problem, as the solution depends heavily on the specified objective function.

Results All Method 3 Generator

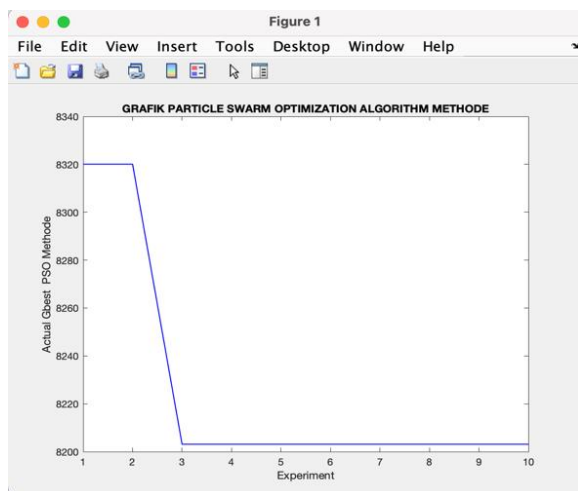


Fig. 4. PSO Output Simulation

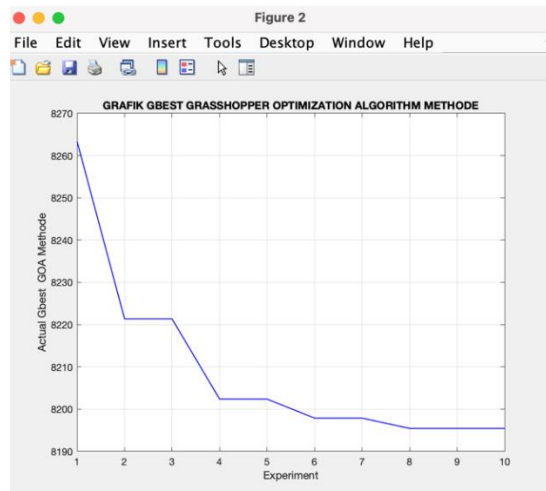


Fig. 5. GOA Output Simulation

Table 4. Generating Load PSO and GOA Method

No	Method	Steam Power Plant 1	Steam Power Plant 2	Combine Cycle Power Plant	Solar	Wind	Total Product (\$/h)
1	Lagrange	393,1698	334,6038	122,2264	0	0	8194,4
2	Priority List	250	400	200	0	0	8263,8
3	PSO	424,2981	283,8557	141,8463	0	0	8202,7
4	GOA	393,13	333,09	123,79	0	0	8194,5

The Lagrangian method yielded a power distribution close to optimal for meeting a load demand of 850 MW, subject to a specified objective function (cost function). In contrast, the Grasshopper method can handle any objective function (cost function) and is therefore more general. The calculation results indicate that the maximum attainable total cost per MWh of generation is approximately \$8,194/MWh. And what can be achieved is the Lagrange Method and GOA.

Power distribution among generators is within specified limits or in accordance with the Demand Load constraint; however, between the Lagrange and GOA methods, the distribution differs across units. The computational cost of the PSO method remains lower than that of the GOA method. This shows the effectiveness of the GOA method in solving the Economic Dispatch problem with 3 Generations.

2. Results Running Program with 5 Generators with PSO and GOA Method

Table 5. Generating Load PSO and GOA Method

No	Time (Hour)	Load Demand	Priority List (\$/h)	PSO (\$/h)	GOA (\$/h)	% Efficiency PSO vs Priority	% Efficiency GOA vs Priority
1	1	165	6943,7	6927,3	6925,8	0,2355	0,2580

No	Time (Hour)	Load Demand	Priority List (\$/h)	PSO (\$/h)	GOA (\$/h)	% Efficiency PSO vs Priority	% Efficiency GOA vs Priority
2	2	170	7063,6	7042,5	7040,7	0,2997	0,3241
3	3	175	7184,6	7157,9	7155,6	0,3722	0,4035
4	4	180	7306,7	7273,7	7271,4	0,4512	0,4829
5	5	185	7423,5	7390	7387,6	0,4515	0,4842
6	6	190	7537,5	7506,7	7503,8	0,4085	0,4474
7	7	195	7652,9	7623,7	7621,4	0,3816	0,4115
8	8	200	7769,8	7741,2	7737,9	0,3681	0,4113
9	9	205	7888,2	7859,1	7856,7	0,3692	0,3990
10	10	210	8008	7977,5	7974,8	0,3808	0,4138
11	11	215	8129,2	8096,2	8092,1	0,4059	0,4563
12	12	220	8251,9	8215,4	8211,9	0,4427	0,4844
13	13	225	8376,1	8335	8330,3	0,4908	0,5461
14	14	230	8501,7	8454,9	8450	0,5498	0,6075
15	15	235	8628,7	8575,3	8571,9	0,6187	0,6579
16	16	240	8757,2	8696,1	8693,2	0,6973	0,7305
17	17	245	8875,8	8817,4	8811,3	0,6584	0,7263
18	18	250	8988,1	8939	8933,8	0,5463	0,6040
19	19	255	9101,7	9061	9054,7	0,4463	0,5164
20	20	260	9216,4	9183,6	9176,8	0,3561	0,4299
21	21	265	9332,3	9306,5	9303,5	0,2769	0,3085
22	22	270	9449,4	9429,8	9422,2	0,2075	0,2880
23	23	243	8831,2	8768,9	8763,2	0,7058	0,7701
24	24	177	7229,1	7204,2	7201,9	0,3444	0,3770

Figure 6 compares total generation costs (Total Generating Cost / Total Product Cost) over 24 hours (Time Hours) using three methods: Merit Order, PSO (Particle Swarm Optimization), and GOA (Grasshopper Optimization Algorithm).

Table 6. Comparison of Gbest for each experiment with Iteration and Particle Variations

Scenario	Population	Iteration	Load (MW)	Avg PSO	Avg GOA	Std PSO	Std GOA
S1	10	10	200	7750.6	7742.19	137.887	53.815
S2	100	100	200	7741.3	7739.92	0.0207	16.653
S3	1000	500	200	7741.25	7739.78	0.0326	22.603
S4	100	500	1200	37985.65	37052.36	0.2020	529.041

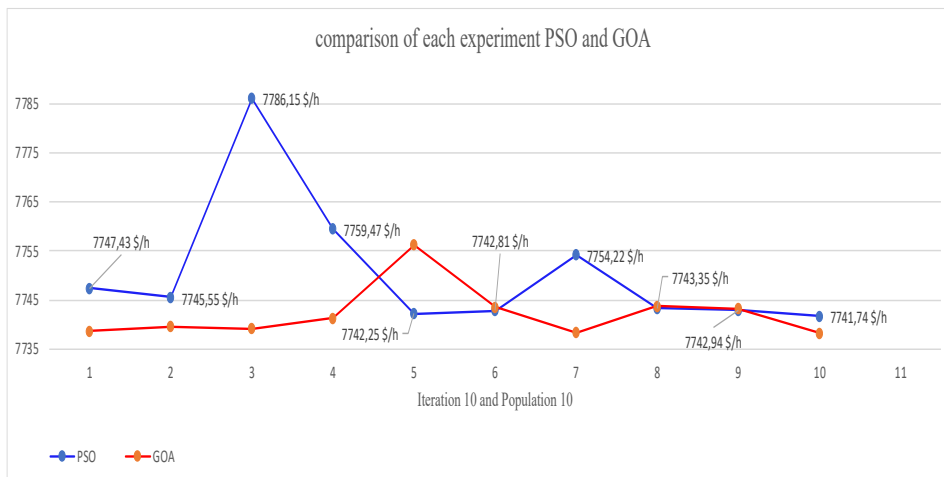


Fig. 6. Curve comparison Output between PSO and GOA

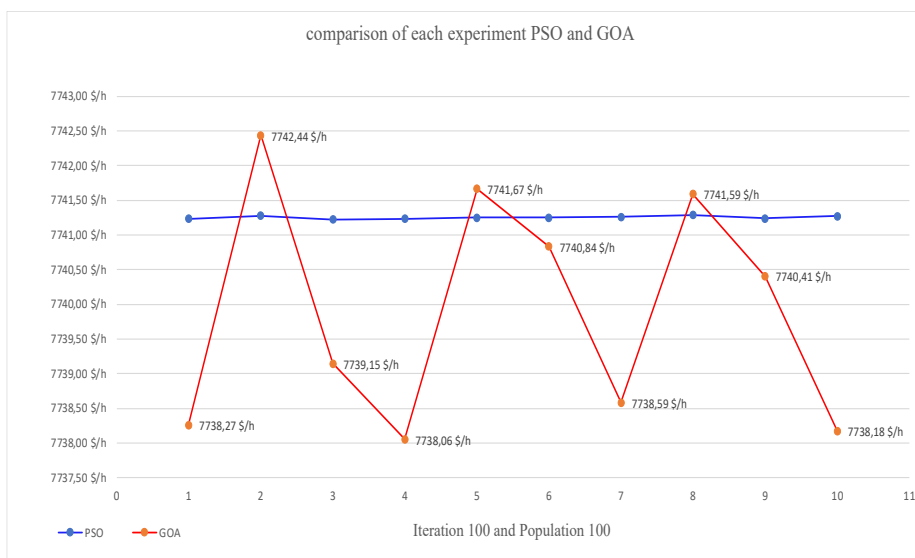


Fig. 7. Curve comparison Output between PSO and GOA

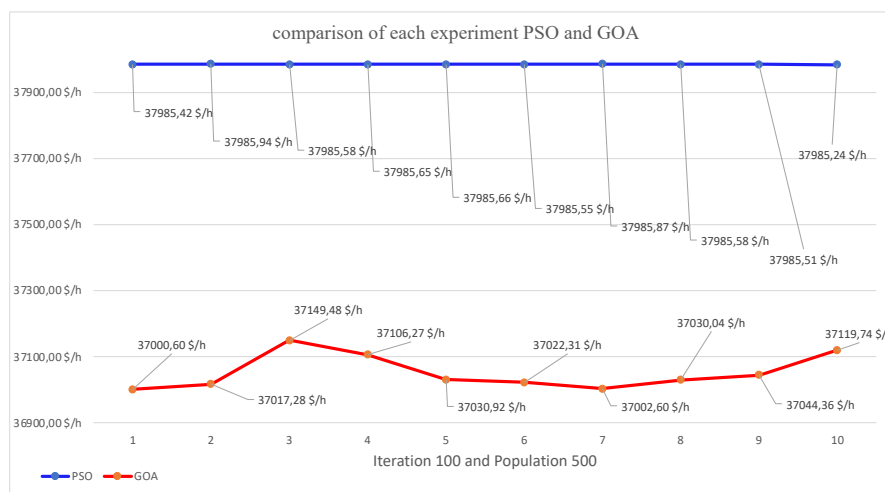


Fig. 8. Curve comparison: Output between PSO and GOA

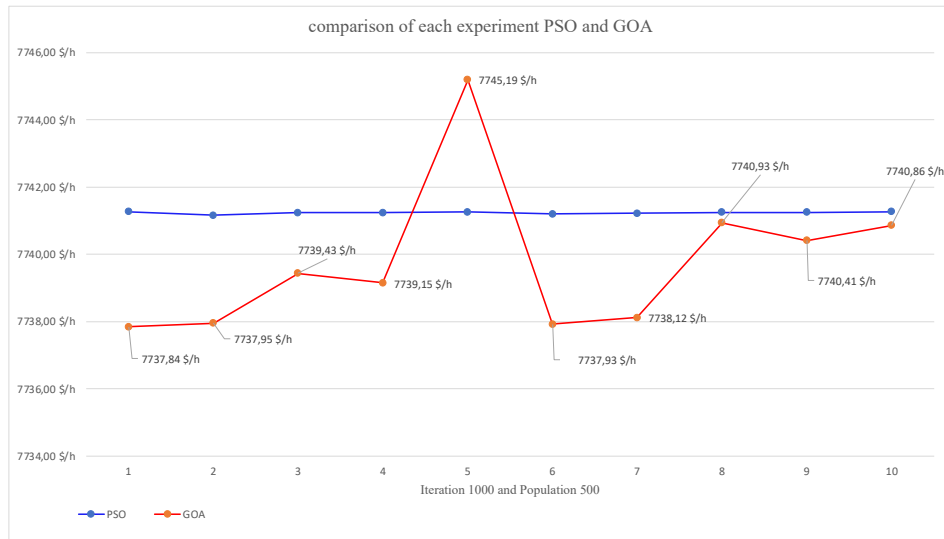


Fig. 9. Curve comparison Output between PSO and GOA

Not only varying the Generate Load but also varying the number of Particles and the Number of Iterations, the Grasshopper Method can outperform every Generating Load produced with the lowest Gbest value, not quite there. It is also necessary to conduct experimental iterations; Table 6 compares the Gbest results for the PSO and PSO methods. Figures 6,7,8,9 show a comparison of Gbest results with different populations and iterations. The image of the scatter diagram curve (scatter plot) or line curve (line plot) shows a comparison of the accuracy results between PSO and GOA, and we can use it to see trends and comparisons of the two methods.

The line chart above compares generation costs (OrGbest, \$/h) between PSO (blue lines and circles) and GOA (red lines and crosses) across all experiments.

Some essential points that can be observed from this Curve are

1. **Stability**
PSO appears highly stable in the last two experiments, with costs ranging from \$7,741.24 to \$7,741.29/h.
2. **Variability**
GOA results are more variable than PSO, with costs ranging from approximately \$7,738.06 to \$7,742.44/h.
3. **Average Optimal Solution Gbest**
In general, PSO tends to provide more consistent and stable results than GOA. However, the GOA method yields better results because it gives a higher-quality Gbest solution.

Based on the calculations from the data above, conclusions can be drawn.

PSO

Average: 7744.4 \$/h with Standard deviation: 0.020 \$/h

Average Cost GOA has a lower average cost (7739.92 \$/d) than PSO (7741.26 \$/d), indicating that, in general, GOA tends to produce more economical solutions.

GOA

Average: 7740.6 \$/h with Standard deviation: 1577 \$/h

The variability (Consistency) of PSO has a much smaller standard deviation (0.020 \$/d) than that of GOA (1.577 \$/d). This indicates that PSO results are more consistent and stable, whereas GOA exhibits greater variability across experiments. Although it shows a higher standard deviation than PSO, GOA exhibits a decreasing standard deviation as population size and the number of existing iterations increase.

V. CONCLUSION

Determining the load on the microgrid network is essential to ensure efficient and stable energy distribution. Microgrids must be set up to meet load demands reliably and sustainably. MATLAB enables simulation and analysis to determine the optimal configuration for microgrid load optimization, as shown in the Simulation Results.

Optimization of energy generation in the electricity network can be achieved using the Lagrange method, Particle Swarm Optimization (PSO), and Grasshopper Optimization Algorithm (GOA). Lagrangian optimization solves optimization problems subject to constraints. In contrast, PSO and GOA, which are metaheuristic-based, aim to minimize operational costs and maximize generation efficiency, achieving average PSO efficiency of 0.4% and GOA of 0.5% relative to the Priority List method.

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