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RESEARCH ARTICLE/ARAŞTIRMA MAKALESİ

ECONOMIC DISPATCH PROBLEM INCLUDING RENEWABLE ENERGY USING MULTIPLE METHODS

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Abstract

The successful design and operation of any power system is highly dependent on the economic load dispatch problem, therefore it can be considered as a major factor for any power system. Economic load dispatch (ELD) problem is the short-term determination of the best combination of generation while satisfying the demanded load with minimum cost under the system constrains. Generally, the cost function presented as quadratic function and solved by using different methods. For the past ten years, in order to solve (ELD) problems and to get the best possible results, many new methods have been developed such as meta-heuristic algorithms which are classified into two major classes (swarm intelligence and evolutionary) techniques. In this paper, two (swarm intelligence) optimization techniques are used, namely salp swarm algorithm (SSA) and grasshopper optimization algorithm (GOA) which are relatively new techniques. The (ELD) analytical method, simplified version of the analytical method and optimization techniques (SSA, GOA) applied to a microgrid considering the renewable energy sources (solar and wind) for different generation combination scenarios. At last, a comparison presented between the used methods in order to show the best result possible between them, in addition the result will show the effect of the renewable energy on the total generation cost. The proposed methods (analytical method, the simplified version of the analytical method and the salp swarm algorithm (SSA)) the same results for total average cost approximately (7292.64 $/h) but the execution time was better with the simplified version of the analytical method with time of (0.373 seconds), while the grasshopper optimization algorithm (GOA) showed a higher total cost average approximately (7292.94 $/h).

Keywords: ELD. Algorithms, Optimization, SSA, GOA, Microgrid, Renewable Energy.

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ÇOKLU YÖNTEMLERLE YENİLENEBİLİR ENERJİNİN EKONOMİK DAĞITIM PROBLEMİ

Özet

Herhangi bir güç sisteminin başarılı bir şekilde tasarlanması ve çalıştırılması, büyük ölçüde ekonomik yük tevzi(dağıtım) problemine bağlıdır, bu nedenle herhangi bir güç sistemi için önemli bir faktör olarak düşünülebilir. Ekonomik yük tevzi(ELD) problemi, sistem sınırlaması altında istenen yükü en düşük maliyetle karşılarken, en iyi nesil/jenerasyon düzeninin kısa süreli olarak belirlenmesidir. Genel olarak, ikinci derece fonksiyon olarak belirtilen maliyet fonksiyonu, farklı yöntemler kullanılarak çözülmüştür. Geçtiğimiz on yıl boyunca, ekonomik yük tevzi sorunlarını çözmek ve en iyi sonuçları elde etmek için, iki ana kategoriye ayrılan (sürü zekâsı ve evrimsel) üst-sezgisel algoritmalar teknikleri gibi birçok yeni yöntem geliştirilmiştir. Bu çalışmada, yeni teknikler olan planktonik tunikap (salp) sürü algoritması (SSA) ve çekirge optimizasyon algoritması (GOA) olmak üzere iki (sürü zekası) optimizasyon teknikleri kullanılmıştır. Ekonomik Yük Tevzi (ELD) analitik yöntemi, farklı nesil kombinasyon/düzen senaryoları için yenilenebilir enerji kaynaklarını (güneş ve rüzgar) göz önünde bulundurarak bir mikro şebekeye uygulanan analitik yöntem ve optimizasyon tekniklerinin (SSA, GOA) basitleştirilmiş versiyonudur. Sonuç olarak, aralarındaki mümkün olan en iyi sonucu göstermek için kullanılan yöntemler arasında sunulan bir karşılaştırma, sonuca ek olarak, yenilenebilir enerjinin toplam üretim maliyetine etkisini de gösterecektir. Önerilen yöntemler (analitik yöntem, analitik yöntemin sadeleştirilmiş versiyonu ve salp sürüsü algoritması (SSA)) yaklaşık olarak ortalama toplam maliyet için aynı sonuçları (7292.64 $/h) ancak uygulama süresi analitik sadeleştirilmiş versiyonuyla daha iyi (0.373) 'e dayanan yöntem, çekirge optimizasyon algoritması (GOA) yaklaşık olarak (7292.94 $ /h) daha yüksek bir toplam maliyet göstermiştir.

Anahtar Kelimeler: Algoritmalar, Çekirge optimizasyon algoritması, Ekonomik yük tevzi, Mikro şebeke, Optimizasyon, Planktonik Tunikap (Salp) sürü algoritması, Yenilenebilir enerji.

1. INTRODUCTION

Meeting the variation of the demanded power in electrical power systems is the reason that by those systems designed, and it is important to minimize the operation cost of the generation units, therefore economic load dispatch (ELD) and many other optimization methods are used to minimize operation cost. Economic load dispatch determines the generation units output to fulfill the required load with as low cost as possible while the system constraints are satisfied (Kaur and Bhaullar, 2011).This paper will implement an analytical method and a simplified version for the economic dispatch problem.

Mathematical optimization is mainly dependent on gradient-based information of the related functions for the sake of finding the best solution, which in our case minimizing the generation costs of a micro-grid. Even though different researchers are still using such techniques, some drawbacks are still associated with them. Methods of mathematical optimization have the problem of local optima entrapment. Which indicates that an algorithm assumes that a local solution is the global one, thereby failing to get the global optimum. They are as well typically ineffective for issues of unknown or computationally expensive derivation, (Mirjalili, M.Mirjalili and Lewis, 2014).

For the past years, studies have been focusing on solving the (ELD) issue, including various types of constraints or numerous objectives and applying many mathematical optimization techniques to solve (ELD) problem, (Wood and Wollenberg, 1996) some of these techniques are the meta-heuristic algorithms. Meta-heuristic algorithms approaches became quite popular over the last decade; the reasons for these techniques' popularity are flexibility, gradient-free mechanism, and avoiding the local optima. Flexibility and gradient-free mechanism are advantages that originated from the fact that meta-heuristics consider and solve the problem of optimization by only taking into count the inputs and outputs, therefore, there is not any need for derivative of the search space, which will allow (nature inspired) meta-heuristic algorithms to solve a wide range of tasks. Those algorithms are categorized into two fundamental classes, which are evolutionary and swarm intelligence (Mirjalili and colleagues, 2017).

This study will use swarm intelligence specifically:

1. Salp swarm algorithm (SSA): this algorithm inspired by the behavior of the salps in seas. One of the most significant behaviors of salps is their swarming behavior. Deep in the oceans, they usually form swarms, which referred to as salp chains. The fundamental cause of the salps behavior is not entirely understood yet, but some scientists have a theory that this is done to achieve better locomotion with the use of rapid coordinated changes and foraging Mirjalili and colleagues, 2017).
2. Grasshopper optimization algorithm (GOA): The presented method mathematically structures and mimics the behavior of swarms of grasshopper in nature to solve optimization tasks. Previous studies results have indicated that the presented algorithm can provide better results in comparison with the well-known and modern algorithms. The real applications prove the features of GOA as well in solving real issues with unknown search spaces (Mirjalili, Saremi and Lewis, 2017).

The previously mentioned methods applied for the minimization of generation cost of a microgrid including renewable energy sources (solar and wind) generation.

A microgrid is a group of electrical sources and loads operates as a single unit, which provides electrical power locally, and this will improve the reliability and the security of the system (Augustine, et al. 2012). Individual distributed generators applications could result in as many issues as it can solve. A more suitable way of realizing the growing potentials of distributed generation is taking a system approach that considers associated and generation loads as a sub- system or a "microgrid". At times of disturbances, the corresponding and generation loads could separate from the distribution system for isolating the load of the micro-grid from the disturbance (which provides UPS services) with no harm to the integrity of the transmission grid. This ability to island generation and loads together could ensure a better local reliability than the one that provided by the power system as one unit (Lasseter and Paigi, 2004). This study proposes a micro- grid, which includes two traditional generators, CHP (combined heat and power) generator, solar generator and wind generator. Moreover, it set to an isolated mode that means the microgrid isolated from the main power system (Augustine, et al., 2012).

Renewable sources of energy, which include biomass, geothermal, wind, ocean, and solar energy, in addition to the hydropower have considerable possibilities for providing the world with energy services. The resource base of renewable energy is adequate for meeting numerous times the current world demand for energy and possibly even (10 – 100) times this demand (Turkenburg et al., 2012) Therefore solar and wind generation are included in this study.

This study will discuss the minimum cost function among the mentioned methods and applied to different generation combination scenarios. In addition, discuss the results and the effect of the renewable energy on the cost for each scenario.

1.1 Litrature Review

For the past decade economic load dispatch (ELD) has become in focus for many studies here are reviews of some previous work:

Noel Augustine, et al (Augustine, et al., 2012) presented an overview to solve the issue of economic dispatch in a micro-grid, which consists of renewable energy. The research utilized the approach of reduced gradient for solving the issue of economic dispatch. From the study of the system, a conclusion was drawn that incorporating solar energy with renewable energy credits in addition to the wind energy into the micro-grid will eliminate the overall system's generation costs. With that been said the nature inspired algorithms can be beneficial to the objective of minimizing the generation cost as (Neve et al., 2017) presented an algorithm of grasshopper optimization for validating the GOA results with the use of test functions of optimization. Each of the constrained and unconstrained test functions of optimization utilized for the validation of the results that obtained from (GOA) algorithm. A mathematical model has been studied, based on the swarming behavior of grasshoppers in nature. A mathematical model mimics the attractive and repulsive forces between grasshoppers. GOA includes a coefficient adaptively decreasing the comfort zone, which utilized to balance of exploitation and exploration. Finally, the optimal solution, which given by swarm, is considered the optimal solution of the issue of optimization. And (Mirjalili et al., 2017) suggests new algorithms for optimization, referred to as Multi- objective Salp Swarm Algorithm (MSSA) and Salp Swarm Algorithm (SSA), to solve tasks of optimization with single and multiple objectives. Those algorithms tested on a number of mathematical optimization functions for observing and confirming their effective behaviors in the detection of the best solutions for problems of optimization. The salps swarming behavior (i.e. the salp chain) has been the most important inspiration for this study. Two mathematical models suggested for updating the positions of leading and following salps. The simulation of swarm in two-dimensional and three-dimensional space indicated that the suggested models are capable of searching around each of the static and moving sources of food. After the simulation of swarm, the (SSA and MSSA) algorithms designed. In SSA algorithms, the optimal solutions that obtained until that point are be the leading source of food that pursued by the salp chain. An adaptive approach integrated to SSA for balancing exploring and exploiting. For the algorithm of MSSA, a repository designed and utilized for storing non-dominated solutions that obtained to that point. The Solutions eliminated from areas of population in a full repository case and the food source selected. Based on the simulations, analyses, results, finding, conclusions, and discussions, the work has stated that the algorithms of SSA and MSSA have traits amongst the existing algorithms of optimization and worth applying to a variety of issues. In addition to the optimization and economic load dispatch techniques, there is an additional consideration that can improve the solution as (Meiqin et al., 2010) presented a model of multi-objective economic dispatch, which considers generation, environmental impact, and reliability. The suggested model can coordinate the cost of production, the cost of consumer outage, and environmental cost coordinated comprehensively with the use of fuzzy multi objective optimizing approach and particle swarm algorithm. With the concept of ensuring the safety and reliability of microgrid operation, multi- objective structure can accomplish energy-conservation scheduling reach more reliability and environmental advantages at the minimum cost.

(Ramanathan, 1985) Presented a considerably efficient, fast, simple, and reliable economical dispatch algorithm. It utilized a closed form expression to calculate Lambda, in addition to dealing with loss changes of total transmission because of the generation change, this way evading any iterative procedures in the computations. The closed form expression that presented for Lambda can be manipulated with all types of incremental transmission loss calculation. For this method, penalty factors derived according to Newton's approach.

(Anderson and Bone, 1980) Describes physiology of communication along the salp chain also how the salp passes the signal from one to another for the swimming coordination purposes observed in several cases like swimming toward food source or swimming to avoid obstacle , in addition to overview of the salp as a creature and salp chains.

(Al Farsi et al., 2015) presented an overview of the problem of economic dispatch, its formulation, and compared addressing the issue between the vertically integrated market and the liberalized market environments. The benefits of the vertically integrated power system are its simplicity and accuracy. In addition, this work states that the drawback of the vertically integrated power system is the incentives for innovation, in general considered weak, except for the case where governments in particular involved in supporting researches and development section in fields of dispatching the power efficiently and economically. However, the liberalized market environment deals with the drawbacks of the vertically integrated model according to low level of efficiency, lack of innovation and, in some cases, extremely high costs. Energy provider has to compete for providing power efficiently.

(Chen et al., 2013) presented a model of energy management utilized for the determination of best operating strategies with maximal benefit for micro-grid systems in Taiwan. The smart micro-grid system is suitable for energy storage devices, systems of wind power generation, and photovoltaic power. Investment sensitivity analyses in storage capacity and growth in energy demands conducted for the smart microgrid structure. The findings have shown that suitable capacity of battery must be determined based on each of power supply and battery efficiency.

(Natesan et al., 2014) Presents a Comprehensive survey on microgrids in each of grid tied and isolated mode for the sake of improving the power quality parameters. All approaches expressed in this survey concentrate on the various problems related to power quality, because of the increased utilization of non-linear loads and power electronic interfaced distributed generation systems. This is why various power quality improvement methods such as optimization approach, facts devices, filters, controllers, compensators, and battery storage successfully overviewed in this research.

2. METHODOLOGY

The purpose of the study is to determine the best operating cost possible for a microgrid considering renewable energy. In this research, the designed model for the economic dispatch and optimization problem will be presented. In addition to the design, the process of implementing different ELD and optimization methods to the design will be discussed.

2.1 The System

The designed model is a microgrid consists of two conventional generator, combined heat and power (CHP) generator, solar generation and wind generation. The microgrid is set on isolated mode, which means it operates independently from the main power station (Ahn and Moon, 2009). The economic load dispatch, the salp swarm algorithm (SSA) and the grasshopper optimization algorithm (GOA) is programed and implemented using matlab R2017b runs on DELL laptop with i5 intel 1.8GHZ processor and 4 GB ram. In addition, the data set for the conventional generators and the (CHP) used from (Augustine et al., 2012). The data set consists of the demanded load for 24 hours, the cost function coefficients and the output power for the renewable energy as shown in the tables below.

Time (hours)	Load (MW)	Time (hours)	Load (MW)
1	140	13	240
2	150	14	220
3	155	15	200
4	160	16	180
5	165	17	170
6	170	18	185
7	175	19	200
8	180	20	240
9	210	21	225
10	230	22	190
11	240	23	160
12	250	24	145

Table 1. The Demanded Load for 24 Hours

Time (hours)	Solar generation (MW)	Time (hours)	Solar generation (MW)
1	0.00	13	31.94
2	0.00	14	26.81
3	0.00	15	10.08
4	0.00	16	5.30
5	0.00	17	9.57
6	0.03	18	2.31
7	6.72	19	0.00
8	16.98	20	0.00
9	24.05	21	0.00
10	39.37	22	0.00
11	7.41	23	0.00
12	3.65	24	0.00

Table 2. The Solar Generation for 24 Hours

Time (hours)	Wind generation (MW)	Time (hours)	Wind generation (MW)
1	1.70	13	14.35
2	8.50	14	10.35
3	9.27	15	8.26
4	16.66	16	13.71
5	7.22	17	3.44
6	4.91	18	1.87
7	14.66	19	0.75
8	26.56	20	0.17
9	20.88	21	0.15
10	17.85	22	0.31
11	12.80	23	1.07
12	18.65	24	0.58

Table 3. The Wind Generation for 24

	CHP	Generator 1	Generator 2
γ ($/h)	0.024	0.029	0.021
β ($/h)	21	20.16	20.4
α ($/h)	1530	992	600

Table 4. Cost Function Coefficients

The operating conditions considered ideal, which means the losses and additional reserves are neglected.

The ELD problem and the optimization algorithms applied to the microgrid in four scenarios of generation combination:

1. The two conventional generators and the (CHP) generator.

2. The three generators with the solar and wind generation.

3. The three generators with wind generation.

4. The three generators with solar generation.

2.1.1 Renewable Energy Implementation

In this study, renewable energy is included in the described system above. The renewable energy consists of solar energy and wind energy generation, and since the renewable energy in general considered very variable in the nature so it cannot be considered as dispatchable, therefore it will be considered as a negative load as in Equation (1), and it will be implemented whenever its available (Augustine et al., 2012).

$$P_{demand\ new} = P_{demand\ old} - (P_{solar} + P_{wind}) \quad (1)$$

With that been said the load demand for the scenarios that the renewable energy is included, will be updated from the Equation above, this procedure will be applied for all the used methods.

The cost function for the renewable energy is calculated differently from the conventional generators and the renewable energy will be added to the total cost of the conventional generators according to the case scenario, in order to calculate the cost of the solar energy, the following Equation is applied (Rajput et al., 2017):

$$F(P_{solar}) = al^p P_s + G^E P_s \tag{2}$$

$$a = \frac{r}{[1 - (1 + r)^{-N}]} \tag{2a}$$

Where $F(P_{solar})$ is the cost of the solar generation, while a is the annuitization coefficient, r is the interest rate which is equals 0.09, N is the investment lifetime and equals 20 years, l^p is the investment cost and it equals 5000 \$/kw and G^E is the operation and maintenance cost and equal to 1.6 cent/kw.

The cost function of the wind is calculated using the following Equation (Augustine et al., 2012):

$$F(P_{wind}) = al^p P_w + G^E P_w \tag{3}$$

Where $F(P_{wind})$ is the cost of the wind generation, while a is the annuitization coefficient, r is the interest rate which is equals 0.09, N is the investment lifetime and equals 20 years, l^p is the investment cost and it equals 1400 \$/kw and G^E is the operation and maintenance cost and equal to 1.6 cent/kw. It should be mentioned that the annuitization for the wind is the same Equation for the solar. Furthermore since the output power in calculated in (MW), the cost function that been used is converted from kW to MW and calculated per hour.

2.1.2 Implementing Economic Load Dispatch

For the proposed microgrid economic load dispatch (for the conventional and (CHP) generators) is applied using analytical method which using the following steps to calculate the cost of generation:

Step 1: evaluating the value of lambda (λ) which represented in Equation (4) and stated as (H. saadat, 1999):

$$\lambda = \frac{P_D + \sum_{i=1}^{ng} \frac{P_i}{2\gamma_i}}{\sum_{i=1}^{ng} \frac{1}{2\gamma_i}} \tag{4}$$

Step 2: calculating the value of the required output power for each generator by applying Equation

(5) which represented as (H. saadat, 1999):

$$P_i = \frac{\lambda - \beta_i}{2\gamma_i} \quad (5)$$

Step 3: check the sum of the output power of the generators, the total sum of the generators output power should be equal to the demanded power as stated in Equation (6) (H. saadat, 1999):

$$\sum_{i=1}^{ng} P_i = P_D \quad (6)$$

Step 4: after finding the output power of each generator, now the value of the cost of operation for each generator can be calculated using the quadric cost function shown in Equation (7) which presented as (H. saadat, 1999):

$$C_i = \alpha_i + \beta_i P_i + \gamma_i P_i^2 \quad (7)$$

Step 5: calculating the total cost of generation, which it is the sum of the costs of the used generators and it presented as in Equation (8) which is (H. saadat, 1999):

$$C_t = \sum_{i=1}^{ng} C_i \quad (8)$$

It should be mentioned that the cost of the renewable energy calculated separately as mentioned above and added to the total cost of the conventional generators.

2.1.3 Simplified Version of the Analytical Method

In this subsection, a simplified version of the analytical approach that has been represented above will be introduced. The simplified version combines the following two Equations (H. saadat, 1999):

$$\lambda = \beta_i + 2\gamma_i P_i \quad (9)$$

And

$$\lambda = \frac{P_D + \sum_{i=1}^{ng} \frac{P_i}{2\gamma_i}}{\sum_{i=1}^{ng} \frac{1}{2\gamma_i}} \quad (10)$$

Achieved by substituting Equation (9) into (10), the following Equation will be obtained

$$P_i = \frac{Ƀ + \sum_1^{ng} \frac{\beta_i}{2\gamma_i} - \sum_1^{ng} \frac{1}{2\gamma_i} b_i}{2ç_i \sum_1^{ng} \frac{1}{2\gamma_i}} \tag{11}$$

By applying this Equation, the output power of the generators may be computed without finding the value of lambda (λ) because it will be implemented within the Equation.

After calculating the values of P_i the cost of generation can be calculated normally as described in the analytical method

2.1.4 Salp Swarm Algorithm Implementation

This algorithm might be one of the major newly suggested methods; salps' swarming behavior is considered the main idea of this algorithm

Salp swarm algorithm is similar to other swarm-inspired algorithms, the location of the salps needs to be determined, so its defined by an n-dimensional search space in which n is the number of variables of a certain task, this is why, the location of all of the salps are kept in a 2-D matrix named as x. The food source are denoted as F in the search space as the target of the swarms (Mirjalili et al., 2017).

In order to solve the required optimization problem the following Equations are essentials. The following formula used to update the leader's location:

$$x_j^1 = \begin{cases} F_j + c_1\left((ub_j - lb_j)c_2 + lb_j\right) & c \geq 0 \\ F_j - c_1\left((ub_j - lb_j)c_2 + lb_j\right) & c < 0 \end{cases} \tag{12}$$

Where x^1 presents the location of the first salp (i.e. the leader) in the jth dimension, F_j is the location of the food source in the *j*th dimension, ub_j denotes the upper bound of *j*th dimension, lb_j denotes the lower bound of jth dimension, c_1 , c_2 , and c_3 are random numbers.

The coefficient c_1 is the most significant of the parameters in SSA due to the fact that it balances the exploration, which is defined as follows (Mirjalili et al., 2017).:

$$c_1 = 2e^{-\left(\frac{4l}{L}\right)^2} \tag{13}$$

Where l represents the current iteration and L denotes the maximum number of iterations. While the parameters c_2 and c_3 are random numbers produced in a uniform manner in the intervals [0, 1]. Theses parameters dictates if the following position in the *j*th dimension must be toward positive infinity or negative infinity

Since the time in optimization is iteration, the discrepancy between iteration equals 1, $v_0 = 0$ therefore the formula will be presented as follows (Mirjalili et al., 2017):

$$x_j^i = \frac{1}{2}\left(x_j^i + x_j^{i-1}\right) \tag{14}$$

Where i ≥ 2 and x^i shows the position of i-th follower salp in the j-th dimension.

The ultimate goal of SSA is determining the global optima. On the other hand, the issue is that the global optima of optimization issues is not known, therefore the SSA algorithm begins the approximation of the global optima via the initiation of a number of salps arbitrarily located. After that, it performs a calculation of the fitness of each of the salps, detects the salp that has the optimal fitness, and assigns its location to the variable F as the source food that should to be chased by the group of salps. Meanwhile the coefficient c_1 will be updated with the use of Equation (13). For every one of the dimensions, the location of the leading salp will be updated using Equation (12) and the location of follower salps will be updated using Equation (14) (Mirjalili et al., 2017).

The following steps describe the process of implementation of salp swarm algorithm.

Algorithm : Salp Swarm
1: **Procedure** **Input:** Load, SolarLoad, WindLoad **Output:** TotalConvCost, P, SolarCost, WindCost **2:** Initializes the position of agents in the search space randomly then put the result in array "x" :

```
position = SSAinitialization(SearchAgents_no,dim,ub,lb,sumofx)
        If Boundary no==1
           Positions=rand(Search Agents no, dim).*(ub-lb)+lb;
        End
            If Boundary no>1
                For i=1:SearchAgents_no
                    n = sumofx;
                    m = 1:n;
                    c = convert sum of x to integer
                      If (c > m(size(m)))
                            c = c - 1
                      End
                    a = m *sort(rand)
                    b = diff
                    b = sumofx-sum(b)
                    Positions = b
              End
        End
```

3: Implement Slap Swarm as following:

At first make population and find the negative energy then extract this energy by the Equation below:

Load = Load - (SolarLoad + WindLoad)

4: find the summation of points p_1, p_2, p_3 as follow:

Sum of x = Load;

5: calculate the total cost of (wind + solar) by using the Equations:

SolarCost = a * lp * Ps + GE * Ps

WindCost = a * lp * Pw + GE * Pw

Where a = r / (1 - (1 + 4) ^ (-N));

lp = 5000 * 1000;

Ps = SolarLoad;

Pw = WindLoad;

GE = ((1.6) / 100) * 1000;

6: determine fitness function, which is the cost function.

7: find the optimization solution as follow:

- Initialize the first population of salps where the number of search agents equals 30 and the maximum number of iterations are 1000
- Initialize the positions of Salps
- Calculate the fitness of initial Salps
- Start from the second iteration by starting the main loop, which starts from the second iteration. The Equation (13) implemented to balance the exploration and exploitation of salps, while Equation (12) implemented to update the position of the leader salp. The Equation (14) updates the position of the following salps.

8: End Procedure

2.1.5 Grass Hopper Optimization Algorithm (GOA) Implementation

The algorithm of GOA simulates the grasshoppers' swarming behavior in nature (Mirjalili et al., 2018). The algorithms that are nature-inspired logically split the process of searching to two operations, which are: exploration and exploitation. In the former, the search agents are encouraged to move abruptly, whereas they usually move locally in the process of exploitation. Grasshoppers perform those two tasks, in addition to naturally seeking target. Therefore, if a way can be found to mathematically model this behavior, new nature-inspired algorithm can be designed (Mirjalili Saremi and Lewis, 2017), In order to solve the presented task, the following Equations are important to the solution:

$$\chi_i^d = \alpha \left(\sum_{j=1}^{N_{gs}} \alpha \frac{ub - lb}{2} \times S_f \left(|x_j^d - x_i^d| \right) \times \frac{x_j - x_i}{d_{ij}} \right) \times \overline{T}_d \quad (15)$$

Where α represents the reduction coefficient, which is utilized to reduce the size of the comfort, repulsion and attraction zones, ub and lb are the upper and lower limits, $\overline{Td}$ is the main goal (i.e. the optimal solution) and χi is the location of the grasshopper. In the Equation above, the submission term denotes the grasshopper's location and it applies the phenomenon of interaction of grasshoppers in nature. The term (Rajput et al., 2017).

$\overline{Td}$ denotes the tendency of moving towards food sources

For the grasshopper optimization, the following Equation used to gradually reduce the search space.

$$\alpha = \alpha_{max} - l\frac{\alpha_{max} - \alpha_{min}}{L} \tag{16}$$

Where l is the current iteration, L is the maximum number of iterations.

The following steps describe the process of implementation of grasshopper optimization algorithm.

Algorithm : Grass Hoper
1: **Procedure** **Input:** Load, SolarLoad, WindLoad **Output:** TotalConvCost, P, SolarCost, WindCost **2:** Initializes the position of agents in the search space randomly then put the result in array "x" : X= initialization(N, dim, up, down, sumofx) **If** (size up ==1) **then** X=rand (N, dim).*(up-down)+down; **Else if** size(up >1) **then** **For** i=1 to n n = sumofx m = 1 to n c = convert sum of x to integer s = size(m) **Next** **If** (c > m(s))

c = c - 1;

End if

Else

a = m * sort (rand)

b = sum of x -sum(b)

X= b

Return (rand)

3: Implement Grass Hoper as following:

At first make population and find the negative energy then extract this energy by the Equation below:

Load = Load - (SolarLoad + WindLoad)

4: find the summation of points p_1, p_2, p_3 as follow:

Sum of x = Load;

5: calculate the total cost of (wind + solar) by using the Equations:

SolarCost = a * lp * Ps + GE * Ps

WindCost = a * lw * Pw + GE * Pw

Where a = r / (1 - (1 + 4) ^ (-N));

lp = 5000 * 1000;

lw = 1400*1000;

Ps = SolarLoad;

Pw = WindLoad;

GE = ((1.6) / 100) * 1000;

6: determine fitness function and set the 30 search agents with 1000 iteration

7: find the optimization solution as follow:

- Initialize population of the grasshopper in the search space randomly
- Calculate the fitness of initial grasshoppers
- Find the best grasshopper (target) in the first population
- Starting the main loop for iterations, which apply Equation (16), in the same loop the new position of the grasshopper is calculated by Equation (15).

- Relocate grasshoppers that go outside the search space
- Calculating the objective values for all grasshoppers
- Update the target

8: End Procedure

3. Results

The results of the optimization and the economic dispatch problem will be presented. the following Figures shows the operation time for each method, analytical and the simplified version of the analytical method The Figure 1-2 shows that the operation time for the analytical method is

0.474 sec and simplified version method is 0.373 seconds.

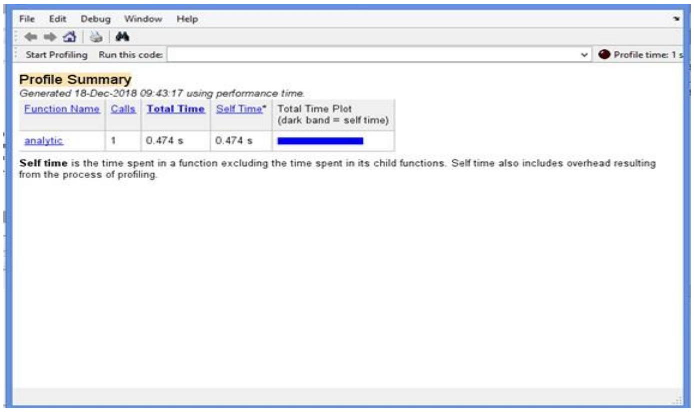

Figure 1. The Operation Time of the Analytical Method

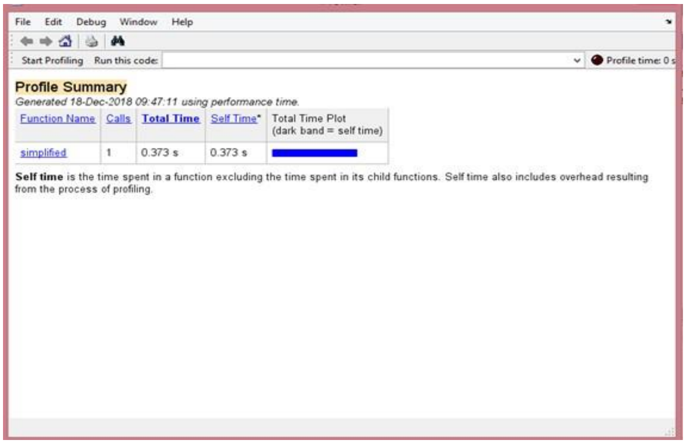

Figure 2. The Operation Time of the Simplified Version

Cost Results will be presented as comparison among the used methods, which are the analytical method, simplified version of the analytical method, salp swarm algorithm (SSA) and grasshopper optimization algorithm (GOA). In addition, the last column of each table will present the minimum cost of each hour. It should be mentioned that since the simplified version better time than the analytical method and it produce the same magnitudes of values it will be considered the best in this comparison regarding the analytical and the simplified version of economic dispatch.in addition the simplified version is preferred as (sim) in the comparison results.

The following Figure shows the graphs of the relation between the cost of generation in (MW) and the time, which is 24 hours for (GOA):

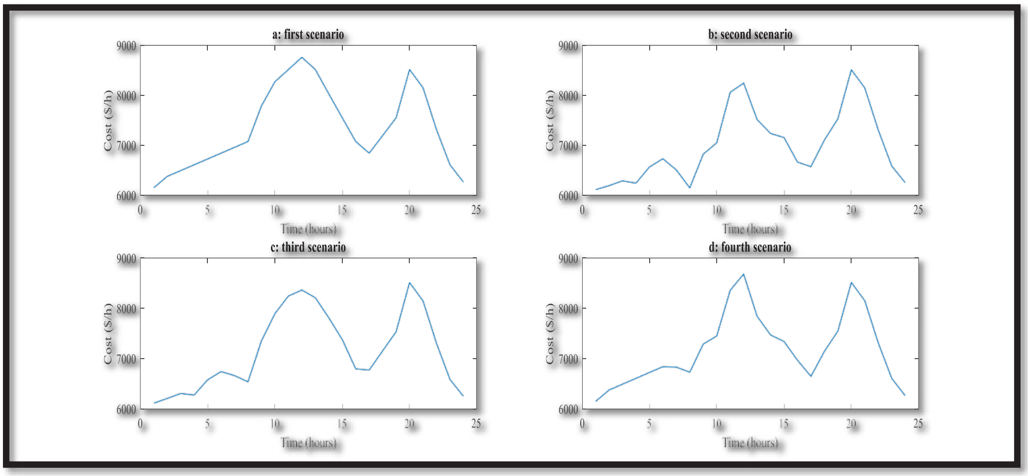

Figure 3. Results of the (GOA) Algorithm.

While the following Figure shows the graphs of the relation between the cost of generation in (MW) and the time, which is 24 hours for (SSA):

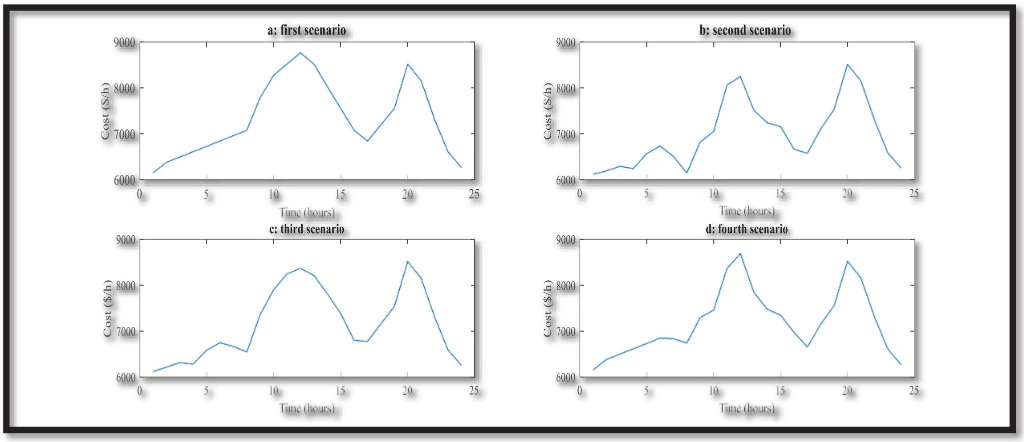

Figure 4. Results of (SSA) Algorithm.

Hours	Simplified & analytical ($/h)	Total cost ($/h) (SSA)	Total cost ($/h) (GOA)	The best cost method	(SSA) vs (GOA)	Best result combination
1	6151.596	6151.596	6152.457	Sim/SSA	SSA	6151.596
2	6380.378	6380.378	6380.386	Sim/SSA	SSA	6380.378
3	6495.375	6495.375	6495.418	Sim/SSA	SSA	6495.375
4	6610.776	6610.776	6611.107	Sim/SSA	SSA	6610.776
5	6726.581	6726.581	6727.216	Sim/SSA	SSA	6726.581
6	6842.79	6842.79	6843.322	Sim/SSA	SSA	6842.79
7	6959.403	6959.403	6959.424	Sim/SSA	SSA	6959.403
8	7076.42	7076.42	7076.442	Sim/SSA	SSA	7076.42
9	7787.005	7787.005	7787.346	Sim/SSA	SSA	7787.005
10	8268.808	8268.808	8268.843	Sim/SSA	SSA	8268.808
11	8512.133	8512.133	8512.21	Sim/SSA	SSA	8512.133
12	8757.075	8757.075	8757.285	Sim/SSA	SSA	8757.075
13	8512.133	8512.133	8512.216	Sim/SSA	SSA	8512.133
14	8027.099	8027.099	8027.177	Sim/SSA	SSA	8027.099
15	7548.527	7548.527	7548.731	Sim/SSA	SSA	7548.527
16	7076.42	7076.42	7076.438	Sim/SSA	SSA	7076.42
17	6842.79	6842.79	6842.976	Sim/SSA	SSA	6842.79
18	7193.841	7193.841	7193.906	Sim/SSA	SSA	7193.841
19	7548.527	7548.527	7549.437	Sim/SSA	SSA	7548.527
20	8512.133	8512.133	8512.277	Sim/SSA	SSA	8512.133
21	8147.751	8147.751	8148.428	Sim/SSA	SSA	8147.751
22	7311.666	7311.666	7312.105	Sim/SSA	SSA	7311.666
23	6610.776	6610.776	6611.382	Sim/SSA	SSA	6610.776
24	6265.785	6265.785	6266.076	Sim/SSA	SSA	6265.785
Total cost average	7340.241211	7340.241211	7340.52523			7340.241211

Table 5. Cost Comparison for First Scenario

Hours	Simplified & analytical ($/h)	Total cost ($/h) (SSA)	Total cost ($/h) (GOA)	The best cost method	(SSA) vs (GOA)	Best result combination
1	6141.552	6141.552	6141.644	Sim/SSA	SSA	6141.552
2	6329.251	6329.251	6329.343	Sim/SSA	SSA	6329.251
3	6438.925	6438.925	6438.929	Sim/SSA	SSA	6438.925
4	6508.973	6508.973	6509.104	Sim/SSA	SSA	6508.973
5	6681.328	6681.328	6681.329	Sim/SSA	SSA	6681.328
6	6811.405	6811.405	6811.653	Sim/SSA	SSA	6811.405
7	6841.27	6841.27	6841.81	Sim/SSA	SSA	6841.27
8	6843.969	6843.969	6844.354	Sim/SSA	SSA	6843.969
9	7540.551	7540.551	7540.631	Sim/SSA	SSA	7540.551
10	7961.806	7961.806	7962.277	Sim/SSA	SSA	7961.806
11	8379.771	8379.771	8380.11	Sim/SSA	SSA	8379.771
12	8597.608	8597.608	8597.651	Sim/SSA	SSA	8597.608

13	8252.409	8252.409	8252.487	Sim/SSA	SSA	8252.409
14	7830.502	7830.502	7830.548	Sim/SSA	SSA	7830.502
15	7447.543	7447.543	7447.588	Sim/SSA	SSA	7447.543
16	6966.404	6966.404	6967.094	Sim/SSA	SSA	6966.404
17	6782.347	6782.347	6782.473	Sim/SSA	SSA	6782.347
18	7171.388	7171.388	7172.215	Sim/SSA	SSA	7171.388
19	7543.363	7543.363	7544.066	Sim/SSA	SSA	7543.363
20	8510.852	8510.852	8511.349	Sim/SSA	SSA	8510.852
21	8146.657	8146.657	8146.817	Sim/SSA	SSA	8146.657
22	7309.58	7309.58	7309.67	Sim/SSA	SSA	7309.58
23	6604.103	6604.103	6604.333	Sim/SSA	SSA	6604.103
24	6262.306	6262.306	6262.392	Sim/SSA	SSA	6262.306
Total cost average	7245.994383	7245.994383	7246.24434			7245.994383

Table 6. Cost Comparison for Second Scenario

Hours	Simplified & analytical ($/h)	Total cost ($/h) (SSA)	Total cost ($/h) (GOA)	The best cost method	(SSA) vs (GOA)	Best result combination
1	6141.552	6141.552	6142.182	Sim/SSA	SSA	6141.552
2	6329.251	6329.251	6329.882	Sim/SSA	SSA	6329.251
3	6438.925	6438.925	6438.926	all	Equal	6438.925
4	6508.973	6508.973	6509.275	Sim/SSA	SSA	6508.973
5	6681.328	6681.328	6681.336	Sim/SSA	SSA	6681.328
6	6811.527	6811.527	6812.207	Sim/SSA	SSA	6811.527
7	6866.031	6866.031	6866.632	Sim/SSA	SSA	6866.031
8	6907.663	6907.663	6907.687	Sim/SSA	SSA	6907.663
9	7643.257	7643.257	7643.802	Sim/SSA	SSA	7643.257
10	8139.714	8139.714	8139.725	Sim/SSA	SSA	8139.714
11	8416.971	8416.971	8417.218	Sim/SSA	SSA	8416.971
12	8616.288	8616.288	8616.449	Sim/SSA	SSA	8616.288
13	8405.627	8405.627	8405.631	Sim/SSA	SSA	8405.627
14	7953.291	7953.291	7953.612	Sim/SSA	SSA	7953.291
15	7492.154	7492.154	7492.698	Sim/SSA	SSA	7492.154
16	6987.886	6987.886	6988.441	Sim/SSA	SSA	6987.886
17	6820.846	6820.846	6820.901	Sim/SSA	SSA	6820.846
18	7181.435	7181.435	7181.446	Sim/SSA	SSA	7181.435
19	7543.363	7543.363	7543.681	Sim/SSA	SSA	7543.363
20	8510.852	8510.852	8511.334	Sim/SSA	SSA	8510.852
21	8146.657	8146.657	8146.868	Sim/SSA	SSA	8146.657
22	7309.58	7309.58	7309.645	Sim/SSA	SSA	7309.58
23	6604.103	6604.103	6604.456	Sim/SSA	SSA	6604.103
24	6262.306	6262.306	6262.914	Sim/SSA	SSA	6262.306
Total cost average	7279.982587	7279.982587	7280.289539			7279.982587

Table 7. Cost Comparison for Third Scenario

Hours	Simplified & analytical ($/h)	Total cost ($/h) (SSA)	Total cost ($/h) (GOA)	The best cost method	(SSA) vs (GOA)	Best result combination
1	6151.596	6151.596	6151.957	Sim/SSA	SSA	6151.596
2	6380.378	6380.378	6380.474	Sim/SSA	SSA	6380.378
3	6495.375	6495.375	6495.456	Sim/SSA	SSA	6495.375
4	6610.776	6610.776	6611.262	Sim/SSA	SSA	6610.776
5	6726.581	6726.581	6726.921	Sim/SSA	SSA	6726.581
6	6842.665	6842.665	6842.937	Sim/SSA	SSA	6842.665
7	6933.157	6933.157	6933.363	Sim/SSA	SSA	6933.157
8	7005.439	7005.439	7006.021	Sim/SSA	SSA	7005.439
9	7676.185	7676.185	7676.433	Sim/SSA	SSA	7676.185
10	8079.544	8079.544	8079.704	Sim/SSA	SSA	8079.544
11	8473.4	8473.4	8473.903	Sim/SSA	SSA	8473.4
12	8737.295	8737.295	8737.303	Sim/SSA	SSA	8737.295
13	8351.509	8351.509	8351.888	Sim/SSA	SSA	8351.509
14	7899.826	7899.826	7900.099	Sim/SSA	SSA	7899.826
15	7502.571	7502.571	7503.075	Sim/SSA	SSA	7502.571
16	7053.764	7053.764	7053.769	Sim/SSA	SSA	7053.764
17	6803.758	6803.758	6804.25	Sim/SSA	SSA	6803.758
18	7183.724	7183.724	7184.175	Sim/SSA	SSA	7183.724
19	7548.527	7548.527	7548.738	Sim/SSA	SSA	7548.527
20	8512.133	8512.133	8512.443	Sim/SSA	SSA	8512.133
21	8147.751	8147.751	8148.427	Sim/SSA	SSA	8147.751
22	7311.666	7311.666	7312.408	Sim/SSA	SSA	7311.666
23	6610.776	6610.776	6611.152	Sim/SSA	SSA	6610.776
24	6265.785	6265.785	6266.369	Sim/SSA	SSA	6265.785
Total cost average	7304.340915	7304.340915	7304.688553			7304.340915

Table 8. Cost Comparison for Fourth Scenario

Average of total cost					Total execution time		
Simplified & analytic ($/h)	(SSA) cost ($/h)	(GOA) cost ($/h)	Best met-hod	Best results combina-tion ($/h)	Simplified & analytic (seconds)	(SSA) Time (se-conds)	(GOA) Time (se-conds)
7292.64	7292.64	7292.94	Sim/SSA	7292.64	(0.373 & 0.474)	2.874	122.37

Table 9. Total Time and Cost of the Four Scenarios

4. CONCLUSION AND FUTURE WORK

This study presents economic dispatch problem on a microgrid including renewable energy (solar, wind) to calculate the minimum cost possible using multiple methods such as analytical method and simplified version of the analytical method, also applying two nature inspired optimization algorithms salp swarm algorithm (SSA) and grasshopper optimization algorithm (GOA). The results of the analytical method and the simplified version showed that as expected, the total cost is identical but the simplified version execution time is better than the analytical method. The execution time varies according to the condition of the used computer, however, the simplified version always showed less time for execution regardless of the computer condition compared to the analytical method at the moment of execution. Even though the simplified version reduces the steps and time for the solution, some cases of studies require knowing the value of lambda and this way of solution will not be able to show that due to the fact that lambda is included within the formula and will not be calculated separately.

The results of the implementation of the proposed (SSA) and (GOA) algorithms shows a dominance in results with the (SSA) algorithm where it showed a better result with less execution time. the optimal solution achieved in the 24th iterations with much less time (2.874 sec) compared to GOA algorithm which took much time to achieve the solution approximately 122.37 second with 24 iterations. The disadvantage in SSA algorithm in this system it requires more time to achieve the optimal solution than the analytical and simplified version methods.

The advantage that been shown in GOA algorithm is that it has high flexibility with the solution that can be suitable for other types of optimization problem.

It can be concluded that, the obtained results showed that for the four-generation scenarios, the analytical method, simplified version of the analytical method and the salp swarm algorithm (SSA) produced the same minimum cost. however, the simplified version of the analytical method presented the fastest execution time among the three methods, so it considered as the best solution method for the proposed system. While the (GOA) algorithm presented the slowest execution time with the highest cost values.

Furthermore, it can be concluded that the used optimization algorithms are more flexible and with the proper alterations, they can be implemented to various types of applications. These optimization algorithms benefit from the avoidance of considering the feasible solution as an optimal solution.

For the ELD methods, the analytical method and the simplified version of the analytical method are very effective for these types of problems.

The different generation scenarios showed that the total cost reduced whenever the renewable energy implemented. In the study, the second scenario where the solar and wind generation implemented showed the best results. As a future work the proposed system can be developed in many ways like extending the solution by adding the losses and reserves, furthermore, the system can include larger number of generating units and testing the new system with additional optimization techniques and the new system will be simulated in a simulation to calculate the best minimum cost. For the renewable energy, the energy credits for solar generation can be added to the calculation to minimize the solar energy generation cost.

Conflict of Interests/Çıkar Çatışması

Authors declare no conflict of interests/Yazarlar çıkar çatışması olmadığını belirtmişlerdir.

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