2021 ICRACOS
INTERNATIONAL CONFERENCE ON RESEARCH AND ACADEMIC COMMUNITY SERVICES

2021 3rd International Conference on Research and Academic Community Services (ICRACOS)
http://icracos.lppm.unesa.ac.id

No. : 46719/UN38.I/DL.01.02/2021

UNESA

CERTIFICATE

This certificate awarded to

Widi Aribowo

as

Presenter Article entitle

Implementation Of The Arithmetic Optimization Algorithm For Economic Load Dispatch

at 2021 3rd International Conference on Research and Academic Community Services (ICRACOS) with theme " Sustainable Innovation in Research and Community Services for Better Quality of Life towards Society 5".

Surabaya, 9th - 10th October 2021

Vice Rector for Academic Affairs,	**Conference Chair,**
Prof. Dr. Bambang Yulianto, M.Pd.	**Dr. Nurhayati, S.T., M.T.**

IEEE INDONESIA SECTION

MTT-S IEEE MTT/AP CHAPTER INDONESIA

UNESA Universitas Negeri Surabaya

Implementation Of The Arithmetic Optimization Algorithm For Economic Load Dispatch

Widi Aribowo
Department Of Electrical Engineering
Universitas Negeri Surabaya
Surabaya, Indonesia
widiaribowo@unesa.ac.id

Reza Rahmadian
Department Of Electrical Engineering
Universitas Negeri Surabaya
Surabaya, Indonesia
rezarahmadian @unesa.ac.id

Mahendra Widyartono
Department Of Electrical Engineering
Universitas Negeri Surabaya
Surabaya, Indonesia
mahendrawidyartono @unesa.ac.id

Aditya Chandra Hermawan
Department Of Electrical Engineering
Universitas Negeri Surabaya
Surabaya, Indonesia
adityahermawan@unesa.ac.id

Ayusta Lukita Wardani
Department Of Electrical Engineering
Universitas Negeri Surabaya
Surabaya, Indonesia
ayustawardani@unesa.ac.id

Unit Three Kartini
Department Of Electrical Engineering
Universitas Negeri Surabaya
Surabaya, Indonesia
unitthree@unesa.ac.id

2021 3rd International Conference on Research and Academic Community Services (ICRACOS) | 978-1-6654-4334-0/21/$31.00 ©2021 IEEE | DOI: 10.1109/ICRACOS53680.2021.9701999

***Abstract*— This paper presents the completion of the economic load dispatch on the power system using the latest metaheuristic named Arithmetic Optimization Algorithm (AOA). This algorithm uses the classification conduct of the major math operators such as addition (A), subtraction (S), multiplication (M), and division (D). The optimization process in various search spaces is modeled and applied AOA mathematically. To get the performance of the proposed method, this study uses mathematical methods as a comparison, namely Differential Evolution (DE), Particle Swarm Optimization (PSO), and Sine Tree-Seed Algorithm (STSA). This study uses 2 experimental tests. From the research, it was found that the AOA method is better than the math and PSO methods. The generation cost of the AOA method is better than the PSO method by 0.016264%.**

Keywords*—*Economic Load Dispatch, Arithmetic Optimization Algorithm, Metaheuristic, Power system, Artificial Intelligence.

I. INTRODUCTION

Technological developments are accompanied by increasing. The population of course causes the demand for electricity to continue to grow. The role of generators to supply the growing demand for electrical power is strived to be able to work optimally and efficiently with minimum generation costs to meet load demands [1]. However, the ever-increasing consumer demand for electricity has become a constraint on the generation side, coupled with fluctuations in the demand for electrical power on the load side, causing the supply of electricity to become a major requirement.

The availability of non-renewable fossil fuels such as oil and coal is running low every day. This is a problem for the availability of electrical energy. Considering that fossil fuel thermal plants are still the main source of electricity

To meet current consumer needs, optimization of generators in generating power at a minimum price in the electric power system is very necessary [3]. The generation and distribution process in the electric power system for consumer demand requires very large costs.

Economic Load Dispatch (ELD) is a very important instrument in the control and operation of power systems. ELD has the main function to regulate the distribution of the load to each generator to be able to meet the load requirements with the most optimal generation costs.

ELD problems can be solved using classical mathematical equations and computations based on artificial intelligence. Technological developments that are so significantly affect the optimization method. Several new optimization methods have been introduced by several researchers, including their application to solving ELD problems. Some of the latest methods applied by several researchers such as the gray wolf optimization (GWO) method [5-7], Jaya algorithm [8-10], crowd search algorithm [11-13], Teaching-learning based optimization [14-16], and social spider optimization algorithm [17-18].

This study presents the application of the latest metaheuristic method named the Arithmetic Optimization Algorithm. This method was presented by Abualigah et al [19]. This method is inspired by the employ of Arithmetic operators in tackling math issues. The contribution of this paper is the application of the latest method of metaheuristics, namely AOA to overcome ELD. This paper uses 2 experiments to determine the performance and validation of the method used. ELD problem solving is an interesting field because of the many applications of the latest methods. Although the application of many methods is presented. However, there is still a lot of room to be explored to find the best and most efficient solution

This paper is structured as follows: the second section presents the study of ELD and a brief description of the Arithmetic Optimization Algorithm. The results and analysis of the methods applied are explained in the third section. The last section is the conclusion of the research.

II. LITERATURE REVIEW

A. Economic Load Dispatch

Evaluation of the ELD problem is aimed at obtaining the optimal value of the economic cost of the electric power grid in various conditions. This is to g

et a solution to reduce the total cost of fuel consumption. This can be formulated in the following equation 1-5:

$$M(Ft) = \sum_{k=1}^{n} F_k(P_k) = \alpha_k {P_k}^2 + \beta_k P_k + \gamma_k \quad (1)$$

$$\sum_{k=1}^{n} P_k - P_D - P_L = 0 \quad (2)$$

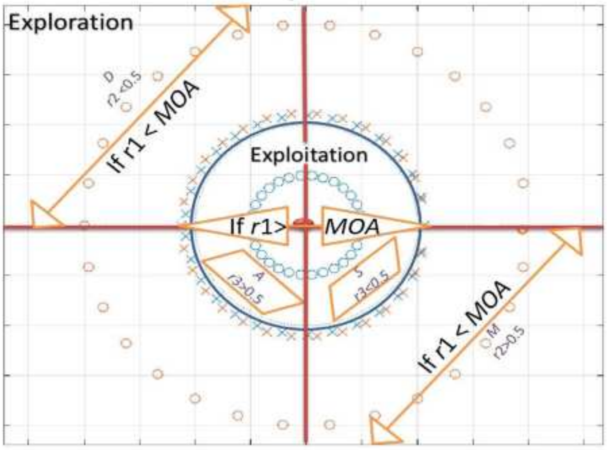


Fig. 1. The search stages [19]

$$P_L = \sum_{j=1}^{n} \sum_{k=1}^{n} P_j B_{jk} P_k \tag{3}$$

$$P_k^{min} \leq P_k \leq P_k^{max} \quad (i = 1, \dots \dots . n) \tag{4}$$

Where Ft is the total cost in *R/h*. F_k is the cost function of *i* the generating unit. P_k is the power of the k th generator. α_k, β_k and γ_k are the weight coefficients of the fuel power cost of *i* th producing unit for the examination and generators ELD issue solving must pay attention to two types of constraints, namely equality constraints and inequality constraints. P_L indicates the final power disadvantages of the transmission lines. P_j and P_k are the real power generations at the j th and k th buses. B_{jk} is the transmission loss coefficients matrix and applied to recognize the power loss. The power generated by the generator must be between its rating (P_k^{min} and P_k^{max}). The cost function has required an estimate of the optimal power unit value while minifying objective criteria (C).

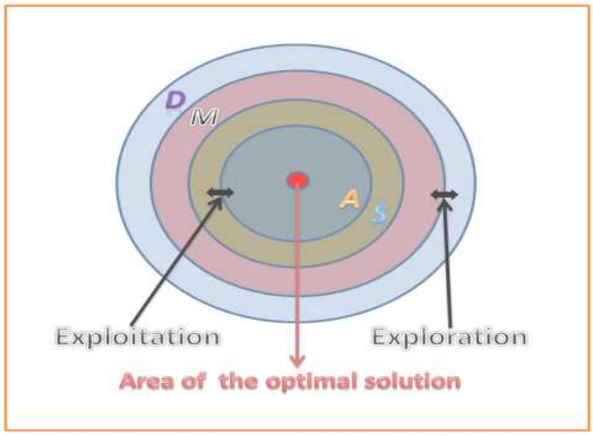
$$C = \sum_{k=1}^{n} C_k(P_k) + \lambda \times abs\left(\sum_{k=1}^{n} P_k - P_D - P_L\right) \tag{5}$$

B. The arithmetic optimization algorithm (AOA)

The basic idea of the AOA method comes from the employ of math syntax in tackling math issues. The basic element of number theory and the core of modern mathematics is arithmetic. Arithmetic operators are computational operations commonly used in studying numbers. AOA applies a simple operation as a computation to set the top element. That is subject to certain criteria from several alternative candidate sets (solutions). Optimization is one of the favorite research fields in all disciplines.

AOA proposes applying Arithmetic operators to represent exploration (diversification) and exploitation (intensive) activities. This algorithm was able to solve optimization problems without calculating the derivative [19].

The AOA algorithm begins with a randomly generated collection of candidate solutions (*X*). The best solution is obtained from the candidate from each iteration. The arithmetic operator hierarchy and its power from outside to inside are shown in Fig 2.



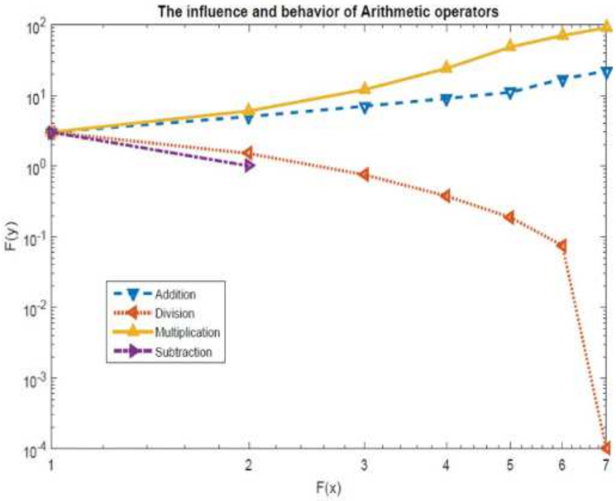


Fig. 3. The effect and conduct of the math operators. [19]

$$X = \begin{bmatrix} X_{1,1} & \cdots & \cdots & X_{1,n} \\ X_{2,1} & \cdots & \cdots & X_{2,n} \\ \vdots & \vdots & \vdots & \vdots \\ X_{m,1} & X_{m,n} & \cdots & X_{m,n} \end{bmatrix} \tag{6}$$

The initial stage of the AOA algorithm is to determine the search phase, namely exploration or exploitation. The Math Optimizer Accelerated (MOA) function is the coefficient used in the search phase. $MOA(C\_Iter)$ shows the value of the function at the *t* th iteration. Mathematically can be formulated in equation 7

$$MOA(C\_Iter) = Min + C\_Iter \times \left(\frac{Max-Min}{M_{iter}}\right) \tag{7}$$

Where C_Iter is the current iteration. M_{iter} is the maximum number. Min and Max are the bottoms and top rates of the expedited function

Exploration phase

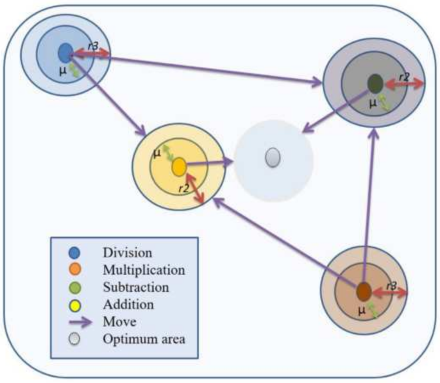


Fig. 4. Reposition of math operators

The division (D) or multiplication (M) operators have a high effect on the exploration search space. On the other hand, operators D and M are difficult to oncoming the target because of their advanced spread. The influence and conduct of math syntax in math computation can be shown in Fig 3,

The AOA exploration operator explores the seeking area disorderly in some areas and approaches to locate an optimum settling based on two major seeking strategies. There is the Division search strategy (D) and Multiplication search strategy. It can be model in Equation (8).

$$X_{i,j}(C_{Iter}+1) = \begin{cases} Best(x_j) \div (MOP+\epsilon) \times \left((UB_j - LB_j) \times \mu + LB_j\right), r2 < 0.5 \\ Best(x_j) \times (MOP) \times \left((UB_j - LB_j) \times \mu + LB_j\right), otherwise \end{cases} \quad (8)$$

$$MOP(C_{Iter}) = 1 - \frac{C_{Iter}{}^{1/\alpha}}{M_{Iter}{}^{1/\alpha}} \quad (9)$$

Where the i,j th the competition in the upcoming iteration is $X_{i,j}(C_{Iter}+1)$ $Best(x_j)$ is the jth position in the best-obtained solution so far. ∈ is a small integer number. The upper bound and lower bound value of the j th position are UB_j And LB_j. A management parameter to adapt the search action is μ . The function value at the tth iteration is $MOP(C_{Iter})$. The maximum of iterations is M_{Iter}. A delicate element and definition of the exploitation fidelity over the iterations is α.

Exploitation phase

In the exploitation phase, the operators used are addition (A) and subtraction (S). Exploitation operators in the AOA algorithm will investigate the seeking area in depth in some compact and contiguous areas. It aims to know an optimum completion based on two major seeking tactics. The exploitation phase can be formulated mathematically in Equation (10).

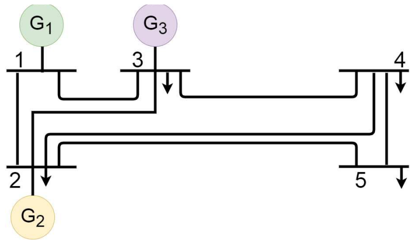


Fig 5. Single line diagram of the electric power system 3 generators - 5 buses [20]

TABLE I. THE OUTPUT OF 3 UNIT POWER PLANT WITH PD = 150 MW

P_1 (MW)	Math method [20]	PSO [21]	DE[22]	STSA[23]	AOA
P_1	33.4701	35.3084	32.79632	32.817346	32.802044
P_2	64.0974	64.3204	64.60567	64.582312	64.59756
P_3	55.1011	52.7259	54.94012	54.942246	54.942426
PL (MW)	2.3419	2.35464	2.34211	2.3419047	2.3420298
Pi (MW)	152.3419	152.355	152.3421	152.3419	152.34203
PD MW)	150	150	150	150	150
Cost ($/h)	1599.98	1597.58	1597.4815	1597.4815	1597.4815

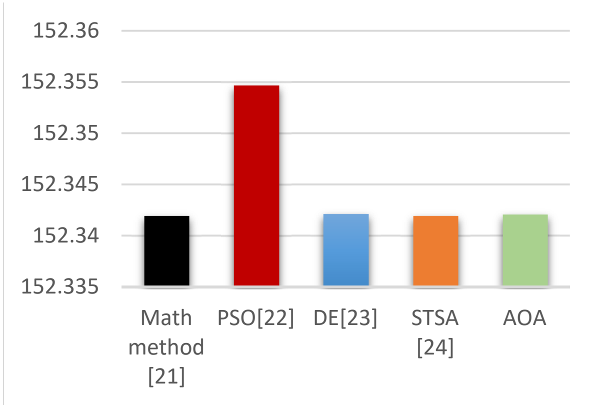


Fig. 6. Chart of the loss transmission in 3 unit power plant

$$X_{i,j}(C_{Iter}+1) = \begin{cases} Best(x_j) - (MOP+\epsilon) \times \left((UB_j - LB_j) \times \mu + LB_j\right), r3 < 0.5 \\ Best(x_j) + (MOP) \times \left((UB_j - LB_j) \times \mu + LB_j\right), otherwise \end{cases} \quad (10)$$

The initial operator (S), in this phase (first rule in Equation (10)), is formed by r3 < 0.5. Meanwhile, the other operator (A) will be ignored until it completes its current job. Otherwise, the second operator (A) will be involved. This procedure helps the exploratory search strategy in seeking the top completion and maintaining the variety of candidates' solutions. These goals to evade obtaining stuck in the local seeking area. The parameter is used to maintain exploration during the iteration process. Fig.4 presents how the search solution for updating a position.

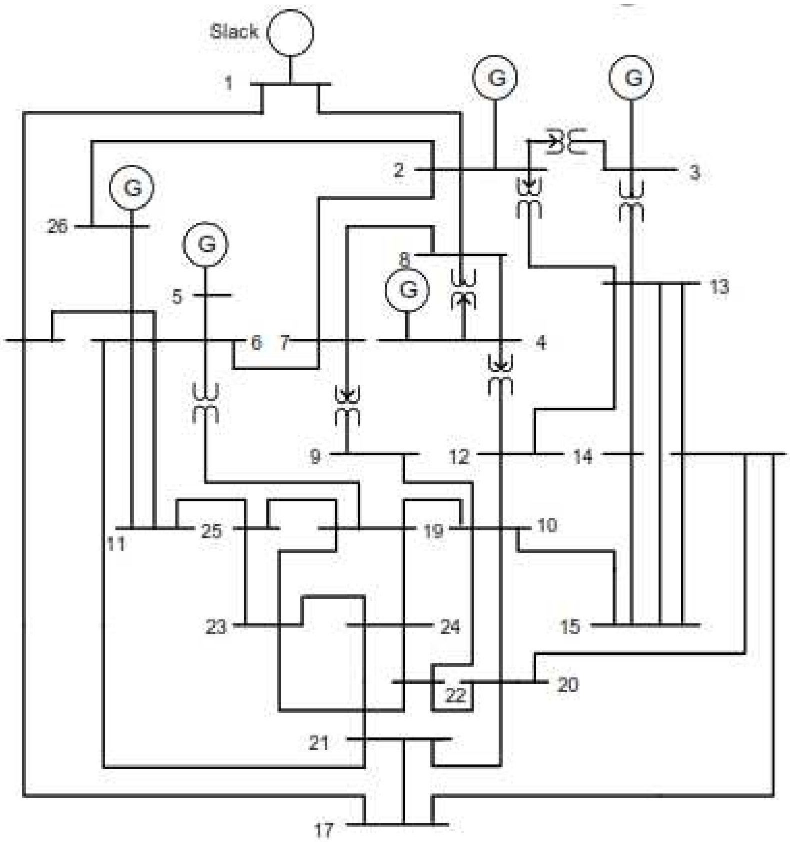


Fig 7. Single line diagram of the electric power system 6 generators - 26 buses [20]

TABLE III. THE OUTPUT OF 6 UNIT POWER PLANT WITH PD = 1263 MW

Generator output (MW)	PSO [21]	DE[22]	STSA [23]	AOA
P_1	440.57656	447.07845	444.64992	443.50548
P_2	167.43691	173.15452	171.71267	171.90682
P_3	278.23561	263.84701	261.15501	267.061263
P_4	150	139.14451	150	141.95909
P_5	157.60614	165.61075	162.73147	166.246907
P_6	81.224444	86.579146	84.953788	84.700373
PL (MW)	12.079658	12.41439	12.202865	12.379943
Pi (MW)	1275.0797	1275.4144	1275.2029	1275.3799
PD (MW)	1263	1263	1263	1263
Cost ($/h)	15445.487	15442.657	15444.023	15442.975

III. RESULTS AND DISCUSSION

To get the performance and validation of the AOA method, this study used 2 experiments, namely 3 units and 6 units of power plants. The data and specifications of the power plant used are derived from the literature.

A. Experiment 1 With 3 Power Generating Units

The first experiment uses three power plants with a load requirement (PD) of 150 MW. Schematic of 3 power plants which are thermal power plants with 5 buses can be seen in Fig 5.

The value of the estimated load on each generator at 3 power plants, the total power generated, power losses, and costs can be seen in detail in table 1. The application of the aoa method obtained a cost of 1597,48152 $ / hour. The cost of the aoa method is the same as the application of the de and stsa methods. On the other hand, the value is better than the math method by 0.15616 % and PSO by 0.0062%. A comparison graph of transmission loss on optimal dispatch can be seen in Fig 6.

B. Experiment 2 With 6 Power Generating Units

The second experiment was 6 units of power plant consisting of 6 units of the thermal power plant. This experiment was conducted to obtain the value of the effectiveness of the AOA method on 6 power plants. A single line diagram of 6 generators with 26 buses can be seen in Fig 7. The estimation results of load, power loss, total and cost, and the cost of generating each unit of the power system in case study 2 with specifications of 6 thermal generating units can be seen in detail in Table 3.

Table 2 is detailed from the estimated load, total power loss, and the cost and cost of generating each power system with 6 thermal power plants. The AOA method has a generation cost of 15442,975 ($/hour). The cost of generation with the application of the AOA method is very thin with the DE method. The generation cost of the AOA method is better than the PSO method by 0.016264%. The PSO method has the largest generation cost in a 6-generation system. The comparison between DE and AOA shows that the value of the generation cost of AOA is slightly higher than that of the DE

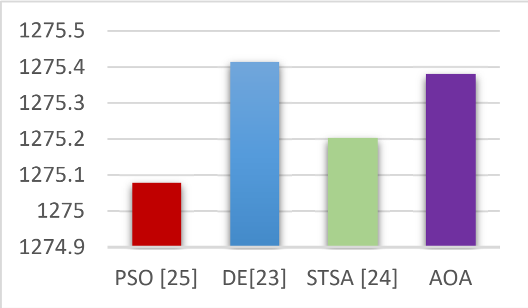


Fig 8. Chart of the loss transmission in 6 units power plant

method of 0.0021%. While the comparison between STSA and AOA found that the value of the generation cost of AOA is smaller than the STSA method of 0.0068%.method. The generation cost of the AOA method is better than the PSO method by 0.016264%. The PSO method has the largest generation cost in a 6-generation system. The comparison between DE and AOA shows that the value of the generation cost of AOA is slightly higher than that of the DE method of 0.0021%. While the comparison between STSA and AOA found that the value of the generation cost of AOA is smaller than the STSA method of 0.0068%.

IV. CONCLUSION

In this study, the solution of the Economic Load Dispatch (ELP) problem has been explored using the Arithmetic Optimization Algorithm. The test uses a power system with 3 and 6 thermal-type power plants. From this study, it was found that the cost of generating the proposed method is better than the math method by 0.15616 % and PSO by 0.0062% in experiment 1. while in the second experiment,
The proposed method has a better generation cost than the PSO method by 0.01626365 %. The AOA method can be further deepened in combination with other methods to get more optimal results

REFERENCES

[1] Aribowo, Widi, Supari Muslim, Bambang Suprianto, Subuh Isnur Haryudo, and Aditya Chandra Hermawan. "Intelligent Control of Power System Stabilizer Based on Archimedes Optimization Algorithm–Feed Forward Neural Network."

[2] Alkoffash, Mahmud Salem, Mohammed A. Awadallah, Mohammed Alweshah, Raed Abu Zitar, Khaled Assaleh, and Mohammed Azmi Al-Betar. "A Non-convex Economic Load Dispatch Using Hybrid Salp Swarm Algorithm." Arabian Journal for Science and Engineering, 2021: pp.1-20.

[3] Aribowo, Widi, Bambang Suprianto, I. Gusti Putu Asto Buditjahjanto, Mahendra Widyartono, and Miftahur Rohman. "An Improved Neural Network Based on Parasitism–Predation Algorithm for an Automatic Voltage Regulator." ECTI Transactions on Electrical Engineering, Electronics, and Communications 19, no. 2, 2021:pp. 136-144.

[4] Al-Betar, Mohammed Azmi. "Island-Based Harmony Search Algorithm for Non-convex Economic Load Dispatch Problems." Journal of Electrical Engineering & Technology, 2021:pp. 1-31.Singh, Diljinder, and J. S. Dhillon. "Ameliorated grey wolf optimization for economic load dispatch problem." Energy 169, 2019: pp.398-419.

[5] Pradhan, Moumita, Provas Kumar Roy, and Tandra Pal. "Oppositional based grey wolf optimization algorithm for economic dispatch problem of the power system." Ain Shams Engineering Journal 9, no. 4, 2018: pp.2015-2025.

[6] Mehmood, K., and A. Ahmad. "Improved grey wolf optimization for economic load dispatch problem considering valve point loading effect and prohibited operating zones." The Nucleus 54, no. 4, 2018: pp.250-257.

[7] Yu, Jiang-Tao, Chang-Hwan Kim, Abdul Wadood, Tahir Khurshaid, and Sang-Bong Rhee. "Jaya algorithm with self-adaptive multi-population and Lévy flights for solving economic load dispatch problems." IEEE Access 7, 2019: pp.21372-21384.

[8] Potfode, A., and S. Bhongade. "Economic Load Dispatch of Renewable Energy Integrated System Using Jaya Algorithm." Journal of Operation and Automation in Power Engineering, 2021.

[9] Farhat, Ibrahim A. "Optimal Economic Dispatch of Thermal-Wind Power Systems with Valve-Point Effects using a Modified JAYA Algorithm." International Journal of Engineering and Information Technology 1, no. 1, 2019:pp. 1-5.

[10] Mohammadi, Farid, and Hamdi Abdi. "A modified crow search algorithm (MCSA) for solving economic load dispatch problem." Applied Soft Computing 71, 2018: pp.51-65.

[11] Spea, Shaimaa R. "Solving practical economic load dispatch problem using a crow search algorithm." International Journal of Electrical and Computer Engineering 10, no. 4, 2020: 3431.

[12] Habachi, Rachid, Achraf Touil, Abdellah Boulal, Abdelkabir Charkaoui, and Abdelwahed Echchatbi. "Solving economic dispatch and unit commitment problem in smart grid system using eagle strategy based crow search algorithm." Indonesian Journal of Electrical Engineering and Computer Science 14, no. 3, 2019:pp. 1087-1096.

[13] Ghanizadeh, Rasool, and Hatef Farshi. "Teaching–learning-based optimization for economic load dispatch." In 2019 5th Conference on Knowledge-Based Engineering and Innovation (KBEI), pp. 851-856. IEEE, 2019.

[14] REDDY, Y. Venkata Krishna, and M. Damodar Reddy. "Solving economic load dispatch problem with multiple fuels using teaching-learning based optimization and salp swarm algorithm." Zeki Sistemler Teori ve Uygulamaları Dergisi 1, no. 1, 2018: pp.5-15.

[15] Joshi, Prachi Mafidar, and H. K. Verma. "An improved TLBO based economic dispatch of power generation through distributed energy resources considering environmental constraints." Sustainable Energy, Grids and Networks 18, 2019: 100207.

[16] T PAVANI, T. SRI SAI SARVANI, and GV APPA RAO. "Economic Load Dispatch Solution Using Teaching Learning Optimization." 2021.

[17] Kien, Le Chi, Thang Trung Nguyen, Chiem Trong Hien, and Minh Quan Duong. "A novel social spider optimization algorithm for large-scale economic load dispatch problem." Energies 12, no. 6, 2019: 1075.

[18] Behera, Soudamini, Sasmita Behera, and Ajit Kumar Barisal. "Dynamic Economic Load Dispatch with Plug-in Electric Vehicles using Social Spider Algorithm." In 2019 3rd International Conference on Computing Methodologies and Communication (ICCMC), pp. 489-494. IEEE, 2019.

[19] Abualigah, Laith, Ali Diabat, Seyedali Mirjalili, Mohamed Abd Elaziz, and Amir H. Gandomi. "The arithmetic optimization algorithm." Computer methods in applied mechanics and engineering 376, 2021: 113609.

[20] Saadat, H. (2008). Power system analysis. McGraw-Hill Companies.

[21] Dewangan, Susheel Kumar, Achala Jain, and A. P. Huddar. "Comparison of particle swarm optimization with lambda iteration method to solve the economic load dispatch problem." International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering 4, no. 4, 2010: pp.1900-1907.

[22] Sheta, Alaa, Hossam Faris, Malik Braik, and Seyedali Mirjalili. "Nature-inspired metaheuristics search algorithms for solving the economic load dispatch problem of power system: a comparison study." In *Applied nature-inspired computing: algorithms and case studies*, pp. 199-230. Springer, Singapore, 2020.

[23] ARİBOWO, Widi. "Comparison Study On Economic Load Dispatch Using Metaheuristic Algorithm." Gazi University Journal of Science: 1-1.