FOREX Publication
Open Access | Rapid and quality publishing

International Journal of
Electrical and Electronics Research (IJEER)
Case Study | Volume 14, Issue 1| Pages 154-159 |e-ISSN: 2347-470X

Optimal Reactive Power Flow in Electrical Networks Using AI-Based Optimization Techniques

Saad Hussein Alhamid[1], **Zena Ez. Dallalbashi**[2] **and Zozan Saadallah Hussain**[3]*

[1]*Power Engineering Mechanic Department, Technical Engineering College, al kunooze University, Iraq; Email: saad.alhamid@kunooze.edu.iq*
[2]*Department of Medical Instrumentation Techniques, Polytechnic College Mosul, Northern Technical University, Iraq; Email: zeina.ez@ntu.edu.iq*
[3]*Department of Electrical Techniques, Polytechnic College Mosul, Northern Technical University, Iraq; Email: zozan.technic@ntu.edu*

***Correspondence:** *Zozan Saadallah Hussain*; *zozan.technic@ntu.edu.iq*

ABSTRACT- This paper shows a new method to enhance the performance of loop electrical systems by finding optimal reactive power. The Bees Algorithm and the Jaya Algorithm are used to determine the optimal settings of control variables such as generator voltage, tap positions of transformers, and reactive power output of shunt compensators. These methods are tested on IEEE 14 and IEEE 30 bus systems. The results show that hybridizing the Bees Algorithm with the Newton Raphson method has a more favorable effect than hybridizing the Jaya Algorithm with the Newton Raphson method in terms of minimizing active power losses and achieving faster convergence to the optimal solution. The performance of these proposed methods is compared with conventional optimization techniques and presented for illustrative purposes.

Keywords: Bees Algorithm, Jaya algorithm, Reactive power optimization, Minimize active power losses.

ARTICLE INFORMATION

Author(s): Saad Hussein Alhamid, Zena Ez. Dallalbashi, and Zozan Saadallah Hussain;
Received: 12/08/2025; **Accepted**: 10/02/2026; **Published**: 10/03/2026;
E- ISSN: 2347-470X;
Paper Id: IJEER1208A12;
Citation: 10.37391/ijeer.140116
Webpage-link:
https://ijeer.forexjournal.co.in/archive/volume-14/ijeer-140116.html

1. INTRODUCTION

The significant economic development that the world has witnessed, especially in the past century, has led to an increased demand for electrical energy. Consequently, power generation must be increased by constructing new power plants or expanding existing ones. Additionally, restructuring the design of transmission and distribution networks is necessary, which entails a substantial increase in financial costs and extended time requirements.

Electrical networks in general, and distribution networks in particular, suffer from a significant increase in actual power losses and a decrease in voltage levels at nodes. Determination of Optimal Reactive Power Flow in Electrical Networks, especially those connected to renewable energy sources, plays a crucial role in reducing these losses and improving voltage levels at electrical nodes. Therefore, in recent years, modern methods based on artificial intelligence algorithms have been utilized to enhance the performance of electrical networks. Reactive power flow in Loop electrical networks is necessary for the operation of the electrical system, but exceeding the reactive power of the permissible ranges may lead to major problems, represented by increasing the active power losses.

Recently, modern methods based on artificial intelligence algorithms have been used to improve the performance of electrical networks, reducing active power loss values and improving voltage values at network nodes. There are many recent studies that have focused on finding the optimal flow for reactive power in electrical networks to reduce actual power losses at lowest possible value and improving voltages at nodes, and we will review the latest of these studies. In reference [1], the learning algorithm (TLBO) was used to find the optimal reactive power flow for a standard IEEE14 - IEEE30 network with the aim of reducing losses and improving voltage, where the value of losses decreased by 8.4% and 8.5%, respectively. In reference [2] particle swarm algorithm is used finding optimal reactive power flow in a realistic network connected with a synchronous generator in two cases: In the first case, without adding a generator, we noticed that the value of actual losses decreased by 15.93%. The second case: When adding a DG generator, the best location was node 39, and the actual losses decreased by 26.67%. As for reference [3], the particle swarm algorithm (PSO) was also applied to an IEEE14 standard network connected to a wind generator and with variable wind speeds, and the losses decreased by 8.6% without connecting a generator, but the percentage of decrease became 11.1% when connecting the generator to node 14, while this percentage became 11.82% when adding two generators in the generation nodes (2 & 6). While in the research [4] the (PSO) algorithm was used to obtain the IEEE_39 radial standard network where the generators' voltages static reactive compensators, and power transformer settings were used as control variables, and compensators were installed at nodes 11 and 12, which showed an improvement in some node voltages and decrease in active power losses by 3.16% and it used an algorithm based Multi-Agent Model with Volt-VAR Control and applied it to an IEEE14 standard network [5]. As for the research [6], it used a new algorithm called JAYA and applied this algorithm to three standard networks, IEEE14, IEEE30, and IEEE57, and it obtained very good results, especially when connecting these networks with distributed generation systems. The research [7] used a hybrid algorithm called CPSO to improve the performance of standard Loop networks, where the actual loss reduction in IEEE14 and IEEE30 was 12.243 MW and 16.01 MW, respectively.

Therefore, in this research, the bees and Jaya algorithms will be used to find the optimal reactive power flow to reduce active power losses, enhancing the voltage profile and the response speed in reaching the optimal solution. This paper is structured as follows: *Section 2* presents the objective function. Offers the Bees and JAYA Algorithms in *section 3*. Applications of the proposed method are in *section 4*. In *section 5* results and Comments. Offers the conclusions of this paper in *section 6*.

2. FORMULATION OF THE OPTIMIZATION PROBLEM

2.1. Objective function

The mathematical equation expressing the active power losses in electrical networks is given by *eq. (1)* in the research [8].

$$Min\ Ploss = F(x,u) = \sum_{K=1}^{Ni} Gi\left(Vi^2 + Vj^2 - 2 * Vi * Vj * cos\delta_{ij}\right) \tag{1}$$

x _It is a vector that includes the non-independent (restricted) variables: Load bus voltage V_L, generator reactive power output Q_G, Transmission line flow) S_L.

u _ It is a ray that includes the control variables, generation bus voltages Vg as a continuous control variable, Transformer taps ratios T, Shunt VAR compensation Qc, both of which are discrete control variables

where P_{loss}: expresses the actual power losses, G_i: is the conductance of branch *i*, *Ni* indicates the total bus count. V_i: and V_j: corresponding voltage bus of *i* and *j*, respectively,

2.2. Constraints

2.2.1. Equality Constraints

equality constraints that are achieved once the Newton-Raphson algorithm starts working and are represented by the relationships *eq. (2)* and *eq. (3)* in the research [7].

$$P_{Gi} - P_{Li} = \sum_{i=1}^{NB} |V_i| * |V_j| * \left(G_{ij} * Cos\delta_{ij} + B_{ij} * Sin\delta_{ij}\right) \tag{2}$$

$$Q_{Gi} - Q_{Li} = \sum_{i=1}^{NB} |V_i| * |V_j| * \left(G_{ij} * Sin\delta_{ij} + B_{ij} * Cos\delta_{ij}\right) \tag{3}$$

Here, NB represents the total number of buses in the system, the terms P_{Gi} and Q_{Gi} denote the active and reactive power generated at bus *i*, respectively, while P_{Li} and Q_{Li} are the active and reactive load demands, G_{ij} and B_{ij} indicate the conductance and susceptance of the line connecting buses *i* and *j*, respectively. finally, δ_{ij} refers voltage phase angle difference between bus *i* and *j*.

2.2.2. Inequality Constraints

(a) Limits of Voltage generation buses:

$$V_i^{min} \le V_i \le V_i^{max} \quad ,i = 1{,}2, \tag{4}$$

$$0.9 \le V_i \le 1.1 \quad PU \tag{5}$$

(b) Transformer tap setting constraints:

$$\mathrm{T_k}^{\mathrm{min}} \le \mathrm{T_k} \le \mathrm{T_k}^{\mathrm{max}} \quad ,k = 1{,}2 \ldots\ldots\ldots .Nk \tag{6}$$

$$0.95 \le \mathrm{T_k} \le 1.1 \quad \mathrm{PU} \tag{7}$$

(c) Capacity limits for switchable capacitor banks:

$$\mathrm{Q_{ci}}^{\mathrm{min}} \le \mathrm{Q_{ci}} \le \mathrm{Q_{ci}}^{\mathrm{max}} \quad ,i = 1{,}2 \ldots\ldots\ldots .Nc \tag{8}$$

$$0 \le \mathrm{Q_{ci}} \le 30 \quad \mathrm{MVA} \tag{9}$$

In this context V_i^{min} and V_i^{max} define the lower and upper voltage limits. T_k^{min} and T_k^{max} shows the maximum and minimum limits of the tap changing of transformers and Q_{ci}^{min} and Q_{ci}^{max} represents the limits of the reactive power injected by the VAR compensators,

3. ALGORITHMS

3.1. The Bees Algorithm

The Bee Algorithm is considered one of the essential algorithms for finding optimal solutions, which was developed at Cardiff University in Britain in 2005 by a group of researchers led by Professor T.D Pham. It is based on the principle of how bees collect nectar in nature. This algorithm is characterized by its simplicity, ease of implementation, and ability to find optimal solutions efficiently [9]. *Figure 1* demonstrates the main steps of the Bees Algorithm [10].

Initially, the Bees algorithm must be prepared with the following parameters [10].

- Population sizing is defined by the number of scout bees(ns).
- Number of best sites(*m*).
- Number of elite sites (*e*).
- Number of recruited bees for elite sites (n_1).
- Number of recruited bees for (*m-e*) sites (n_2).
- Initial size of neighborhood (n_{gh}).

- Limit of stagnation cycles for site abandonment when reaching the maximum number of iterations or reaching a specific absolute error value between the desired solution and the solution obtained from applying the algorithm, and multiple conditions can be combined.

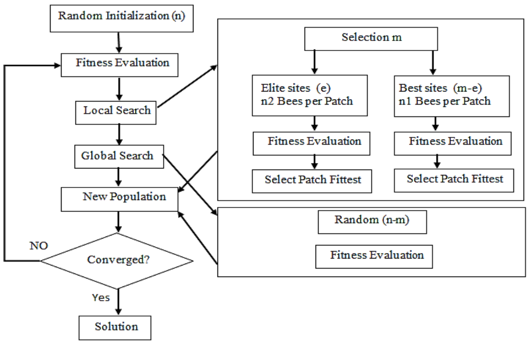

Figure 1. Flowchart of the Bees algorithm

3.2. JAYA Algorithm

Let *f(x)* be the objective function. At iteration *i*, suppose there are (*p*) design variables (*i.e.* *j*=1,2,…,*p*) and (*c*) candidate solutions (*i.e.* population size, *k*=1,2,…,*c*). The candidate solution achieving the highest value of *f(x)* among all candidates is referred to as *F(x)* best, while the candidate with the lowest value is denoted as *F(x)* worst [11]. If ${X^{i}}_{j}$ represents the current value, this value is modified according to *eq. (10)*, which is [12].

$$X'^{i}{}_{j} = x^{i}{}_{j} + r1_j\left(x^{best}{}_j - \left|x^{i}{}_j\right|\right) - r2_j\left(x^{worst}{}_j - \left|x^{i}{}_j\right|\right) \quad (10)$$

Where, $X^{best}{}_j$ is the best solution and $X^{worst}{}_j$ the worst solution, and $r1_J$ and $r2_J$ are the two random numbers in the range [0, 1]. $(r1_J\left(X^{best}{}_j - \left|X^{i}{}_j\right|\right))$ indicates the solution to move closer to the best solution and $r2_j\left(X^{worst}{}_j - \left|X^{i}{}_j\right|\right)$ indicates the solution to avoid the worst solution $X'^{i}{}_j$accepted.

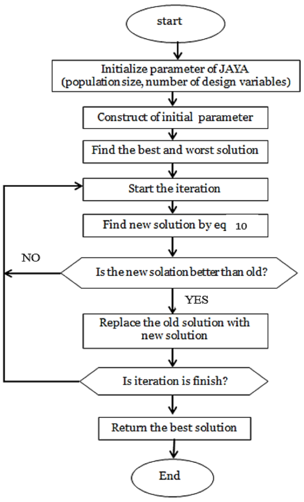

Figure 2. Flow chart of JAYA

When a candidate solution produces a better objective function value, it is retained. The set of accepted solutions at the end of each iteration is used as the starting point for the next. *Fig.2* illustrates the flowchart of the JAYA algorithm. The algorithm moves towards an optimal solution while simultaneously avoiding failure [12].

3.3. Proposed Algorithm Workflow

3.1.1. Bees Algorithm

- *Parameter Initialization:* (Population size – Maximum number of iterations – Number of control variables – Variable boundaries – Data of the studied network, including line parameters, bus voltages, and generation sources.
- *Random Initialization of Control Variables:* Assign random values to the control variables (generator voltages, reactive power of compensators, voltage regulator settings of transformers, and the size and power of the added distributed generation systems) within their appropriate limits.
- *Objective Function Evaluation:* Compute the objective function for these random values, which represents the real power losses. Then, sort the results in ascending order (since the objective is to minimize power losses) by invoking the Newton-Raphson algorithm.
- *Selection of Best Locations:* Select a proportion m of the best locations from the total *n*, and assign *n1* worker bees to explore the neighborhood of these locations in search of better solutions within the given constraints. Then, evaluate the objective function.
- *Selection of Elite Locations:* Select a proportion *e* of the elite locations from the previous m and assign *n2* worker bees to search in the neighborhood of these elite locations to find improved solutions within the defined constraints. Then, evaluate the objective function.
- *Remaining Locations:* For the remaining locations (from *m+1* to *n*), generate new random values and evaluate their objective function. Finally, sort all the results in ascending order and select the first one as the objective function result.
- *Iteration:* Repeat the above steps until the maximum number of iterations is reached or the objective function curve becomes stable, indicating the end of the optimization process.

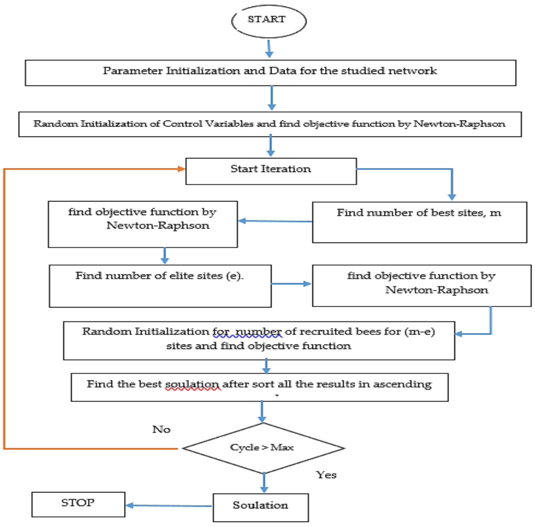

Figure 3. Flow chart of the proposed method

3.3.2. JAYA Algorithm

The first, second, and third steps remain the same as in the Bee Algorithm. In the fourth step, the best and worst values are selected, and these values are improved using *eq. (10)*. If the new value is better than the previous one, it replaces the old value. Otherwise, the optimization process continues based on the previous values.

These steps are repeated until the maximum number of iterations is reached or the optimal solution is found.

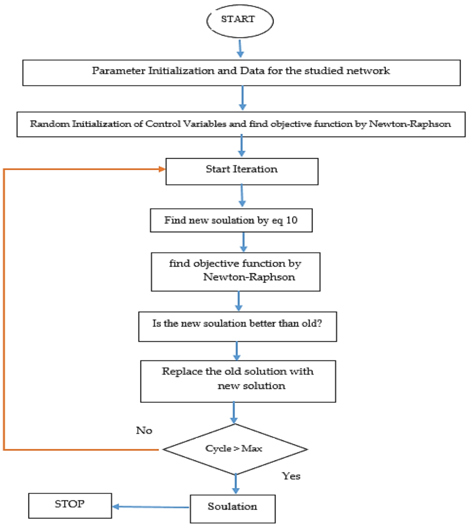

Figure 4. Flow chart of the proposed method

4. SIMULATION RESULTS AND DISCUSSION

Both the Bees and Jaya algorithms are applied to the IEEE 14 and IEEE 30 bus systems. The IEEE 14-bus system includes five generators located at buses 1,2,3,6, and 8, along with twenty transmission lines and three transformers. Additionally, shunt VAR compensating devices were installed at buses 9 and 14 [1]. The IEEE 30-bus system comprises five generators at buses 1,2,5,8,11, and 13. 41 transmission lines and four transformers. The shunt VAR compensating is connected at bus 10 and 24 [1]. The power flow for IEEE 14 and IEEE 30 is calculated using the Newton-Raphson method.

4.1. Case 1

Applying the bee and Jaya algorithms with Newton-Raphson on the IEEE14 network. We can find parameter settings of the bees' algorithm in *table 1* and the Jaya algorithm in *table 2*. The number of control variables is 10, which are (generator voltages number (5), compensator reactive power number (2), transformer voltage regulator number (3).

Table 1. Parameter settings of the bee's algorithm

Max iteration	n1	n2	fittest bees (m)	elite bees (e)	Population (n)
200	10	20	30	9	50

Table 2. Parameter settings of the Jaya algorithm

Max iteration	Population (n)
600	100

Table 3. Control Variables of the bees algorithm

Voltage (pu)					TAP changer (pu)		
V_1	V_2	V_3	V_4	V_5	T_1	T_2	T_3
1.10	1.08	1.05	1.10	1.07	1.00	0.93	1.00
Capacitor (MVAR)							
C_1				C_2			
30.00				6.9987			

Table 4. Control Variables of the Jaya algorithm

Voltage (pu)					TAP changer (pu)		
V_1	V_2	V_3	V_4	V_5	T_1	T_2	T_3
1.10	1.08	1.05	1.10	1.07	1.02	0.91	1.00
Capacitor (MVAR)							
C_1				C_2			
30.00				6.9543			

In *table 5*, we can see a Comparison of the proposed approach with other optimization algorithms as shown below.

Table 5. Comparison of the proposed approach with other optimization algorithms

Algorithm	TLIB [1]	PSO [3]	BA	Jaya
$P_{losses}\%$	8.41 %	8.6 %	9.42%	9.42%

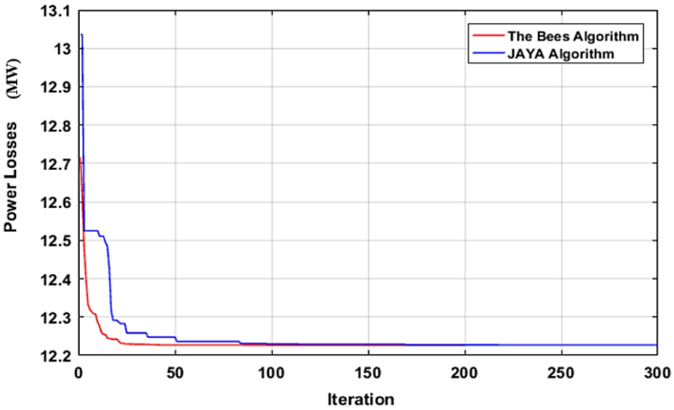

Figure 5. The curve of the decrease in the actual loss values

Table 6. Result of case 1, IEEE14

N_R+ Jaya	N_R + BA	N_R	
12.22MW	12.21 MW	13.49 MW	Power loses
9.42 %	9.48 %	--------------	Power loss reduction %

From *table 6*, we can see that the power losses reduce from 13.49 Mw to 12.21 Mw, *i.e.*, 9.48%. For the Bees algorithm and 9.42 % for the Jaya algorithm, BA has faster convergence to the optimal solution, as seen in *figure 5* from the Jaya Algorithm.

4.2. Case 2

Applying the bee algorithm with Newton Raphson on the IEEE30 network without adding generators. The number of control variables was 12, which are (generator voltages, number (6), compensator reactive power, number (2), and transformer voltage regulator, number (4). They are restricted within the following constraints mentioned in reference [1].

Table 7. Control Variables of the bees algorithm

Voltage (pu)						TAP changer (pu)			
V_1	V_2	V_3	V_4	V_5	V_6	T_1	T_2	T_3	T_4
1.1	1.08	1.05	1.05	1.1	1.1	1.04	0.93	0.97	0.95
Capacitor (MVAR)									
C_1					C_2				
30.0000					10.5404				

Table 8. Control Variables of the Jaya algorithm

Voltage (pu)						TAP changer (pu)			
V_1	V_2	V_3	V_4	V_5	V_6	T_1	T_2	T_3	T_4
1.1	1.08	1.05	1.05	1.1	1.1	1.06	0.90	0.98	0.96
Capacitor (MVAR)									
C_1					C_2				
30.0000					10.9631				

In *table 9*, we can see that the power losses reduce from 17.49 Mw to 15.96 Mw, *i.e.*, 8.70 %. For the Bees algorithm and 8.6 % for the Jaya algorithm. Also, (BA) has faster convergence to the optimal solution, as seen in *figure 6* from the Jaya Algorithm. In *table 10*, we can see a Comparison between the proposed approach and other optimization algorithms.

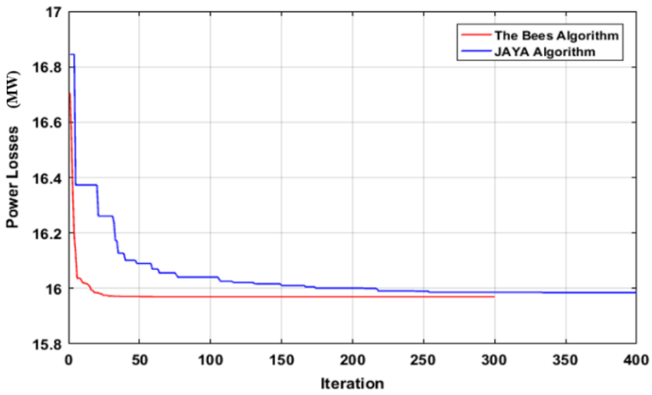

Figure 6. The curve of the decrease in the actual loss values

Table 9. Result of *case 2*, IEEE30

N_R + Jaya	N_R + BA	N_R	
15.9852MW	15.9697 MW	17.4917 MW	Power loses
8.612%	8.701%	-----------	Power loss reduction %

Table 10. Comparison between the proposed method and others

Algorithm	CPSO [7]	SARGA [7]	ABC [7]	Jaya	BA
P_{losses}	16.01	16.09	16.59	15.98	15.96

5. CONCLUSION

From the previous results, we conclude that the proposed algorithm, which is based on integrating the Bees Algorithm with the Newton Raphson method, has given effective performance and good results in solving the problem of finding the optimal reactive power dispatch in electrical power systems. The desired goal of reducing actual power losses and improving the level of efforts while maintaining the imposed restrictions within the permissible range has been achieved, with better results than previous similar research.

Author Contributions: Saad hussein alhamid, writing the necessary programming codes and conducting electrical studies; Zena Ez. Dallalbashi, collecting data on standard electrical networks; Zozan Saadallah Hussain, auditing the data and participating in comparisons. All authors have read and agreed to the published version of the manuscript.

Conflicts of Interest: The authors declare that there are no conflicts of interest regarding the publication of this manuscript**.**

REFERENCES

[1] Nusair K., Alomoush M., Optimal Reactive Power Dispatch Using Teaching Learning Based Optimization Algorithm with Consideration of FACTS Device "STATCOM". The 10th Jordan International Electrical and Electronics Engineering Conference 2017, IEEE, 5386-1836.

[2] Khine Zin Oo., Kyaw Myo Lin., Tin Nile Aung.,2017 " Particle Swarm Optimization Based Optimal Reactive Power Dispatch for Power Distribution Network with Distributed Generation " International Journal of Energy and Power Engineering.

[3] O. Dzobo_ and Y. Sun_2017" Optimal Reactive Power Dispatch of Power System Networks with distributed generation using particle swarm optimization ". University of Johannesburg, Johannesburg, South Africa.

[4] Rayudu K., Yesuratnam G., Ali M, Jayalaxmi A,2016-Optimal Reactive Power Dispatch Based on Particle Swarm Optimization and LP Technique. International Conference on Emerging Technological Trends [ICETT].

[5] Alex Chamba, Carlos Barrera-Singaña, and Hugo Arcos, "Optimal Reactive Power Dispatch in Electric Transmission Systems Using the Multi-Agent Model with Volt-VAR Control," Energies 2023, 16, 5004. https://doi.org/10.3390/en16135004

[6] T.Das,R.roy." Impact of the Penetration of Distributed Generation on Optimal Reactive Power Dispatch" Protection and control of modern power systems@ Springer Open 2020.

[7] Ali Nasser, Ali Abdullah. " Improvement of reactive power dispatch by using Hybrid Intelligent Optimizatin Technique Based on Chaotic and PSO Algorithm" "International Journal of Applied Engineering Research, ISSN 0973-4562 (2018).

[8] M. Ghasemi, M. Taghizadeh, S. Ghavidel, J.Aghaei, A. Abbasian b, "Solving optimal reactive power dispatch Problem Using a Novel Teaching Learning-Based optimisation algorithm," Engineering Applications of Artificial Intelligence, Vol. 39, pp. 100–108, 2015.

[9] D.T. Pham, A. Ghanbarzadeh, E. Koc, S. Otri, S. Rahim, M. Zaidi. "Bee Algorithm: A Novel Approach to Function Optimisation". The Manufacturing Engineering Centre, Cardiff University, 2005.

[10] D.T. Pham, N. Hartono, “Intelligent Production and Manufacturing Optimisation—The Bees Algorithm Approach”. Springer Series in Advanced Manufacturing 2023.

[11] Rao, R. (2016). Jaya: A simple and new optimization algorithm for solving constrained and unconstrained optimization problems. International Journal of Industrial Engineering Computations, 7(1), 19-34.

[12] Zitar, R. A., Al-Betar, M. A., Awadallah, M. A., Doush, I. A., & Assaleh, K. (2022). An intensive and comprehensive overview of the JAYA algorithm, its versions and applications. Archives of Computational Methods in Engineering, 29(2), 763-792.