1. Saad Alhamid[1], 2. Omar hamandouch[1], 3. Ahmed Haj Darwish[2]

University of Aleppo, Syria, faculty of Electrical and Electronic Engineering, Dept. Electrical Power Systems (1)
University of Aleppo, Syria, faculty of Informatics Engineering, Dept. Artificial Intelligence and Natural Languages (2)
ORCID: 3. 0000-0001-6471-852X

doi:10.15199/48.2024.02.39

A hybrid Bees Algorithm to Enhance the Performance of Radial Distribution Systems

***Abstract :** This paper proposes a hybrid algorithm that merges the Bees Algorithm with the JAYA Algorithm and links them with the Backward Forward Sweep Algorithm to find the Optimal Reactive Power Flow in Radial Electrical networks. In addition, determining the optimal location and capacity for compensation capacitors and distributor generation systems to reduce active power losses and improve the profile of voltages in the nodes.The proposed algorithm applied on IEEE 33 and IEEE 69; the results obtained compared with those of other techniques. The comparison showed the effectiveness and robustness of the proposed algorithm. and indicate superiority of hybrid algorithm compared with other optimization algorithms.*

Streszczenie.: *W artykule zaproponowano algorytm hybrydowy, który łączy algorytm pszczół z algorytmem JAYA i łączy je z algorytmem przemiatania wstecznego w przód przy użyciu programu MATLAB w celu znalezienia optymalnego przepływu mocy biernej w radialnych sieciach elektrycznych. Ponadto wyznaczenie optymalnej lokalizacji i pojemności kondensatorów kompensacyjnych oraz układów generacyjnych dystrybutorów w celu ograniczenia strat mocy czynnej oraz poprawy profilu napięć w węzłach. Proponowany algorytm zastosowany w IEEE 33 i IEEE 69; uzyskane wyniki w porównaniu z innymi technikami. Porównanie wykazało skuteczność i solidność zaproponowanego algorytmu. oraz wskazać wyższość algorytmu hybrydowego nad innymi algorytmami optymalizacyjnymi.* (***Hybrydowy algorytm pszczół poprawiający wydajność systemów dystrybucji promieniowej***)

Keywords: The Bees Algorithm, Backward Forward Sweep Algorithm , JAYA Algorithm., distributor generation systems.
Słowa kluczowe: Algorytm pszczół, algorytm przemiatania wstecznego w przód, optymalny przepływ mocy biernej, algorytm JAYA

1- Introduction

Radial electrical distribution networks are an essential part of electrical systems, and they are the link between generation and consumption. These networks were initially designed to be passive systems, meaning that the power flows are in only one direction from the transmission networks to the consumer. However, the advent of renewable energies, which, when linked with distribution networks, formed what is known as distributed generation, which led to the existence of real challenges represented by the flow of power in more than one direction.[1]

The process of concoction of distributed generation systems with electrical systems creates many new challenges in the operation of electrical networks. Like increases the voltages exceeding the permissible values and increases the losses, which appears clearly in the distribution networks. Usually, the active losses are reduced, and the voltage at the loads is improved through the economic and technical operation of these networks by Choosing the optimal placment for the capacitors.[2] As for networks that contain distributor generation, the best way to minimize power losses is chooseing the optimal location and sizing for these systems.

Many recent studies have addressed the issue of finding the optimal location and capacity for capacitors and distributed generation systems in radial power networks have been investigated using different Algorithms. In [3], the Particle Swarm Optimization and whale algorithm were used to determine the optimal placment CB and DG in a radial power network with different loads. But In [4] used Spring Search Algorithm. In [5], the ant algorithm determines the optimal location and capacity for distributed generation systems. Cuckoo Searching Algorithm (CSO) proposed to determine the optimal location and capacity for capacitors and distributed generation systems in IEEE33 and IEEE69. [6]. Biogeography algorithm determines the optimal location and size for solar systems in radial power networks [7]. Also, Honey Badger Algorithm determines the optimal location and capacity for distributed generation systems [8]. And in [9], another algorithm called the whale optimization algorithm to find the optimal location and size for capacitors. Finally, a genetic algorithm determines the optimal location and size for capacitors [10].

Artificial intelligence algorithms' use in finding the optimal location and capacity for capacitors and distributed generation systems has become increasingly important due to their significant technical and economic benefits. In this study, we integrated the Bees Algorithm with the JAYA algorithm.to find the optimal flow of reactive power by selecting the optimal values for control variables (location and capacity for capacitors and distributed generation systems) to improve the performance of the studied network.

This paper is structured as follows. Section 2 presents the objective function. Section 3 offers the Bees and JAYA Algorithms. Applications of the proposed method are in Section 4. The Result and Comments are in Section 5. Finally, Section 6 offers the conclusions of this paper.

Objective function

Finding the minimizing the power loses that expressed in eq (6). This loses depend on sizing and location of capacitor and distributed generation

(1) $$\mathrm{Cost} = \min \sum_{i=1}^{n} P_{T,loss}$$

$P_{T,loss}$: total power loses.

(2) $$\mathrm{P_{T,loss}} = \sum_{i=1}^{n} \mathrm{I_i}^2 * \mathrm{R_i}$$

I_i: is the current magnitude of ith branch.

$\mathrm{R_i}$: is the resistance of ith branch in the network.

Constraints

(3) $$\sum_{1=1}^{n} P_{DG} = \sum_{i=1}^{n} P_{l,i} + \mathrm{P_{T,loss}}$$

(4) $$\sum_{1=1}^{n} Q_{DG} + \sum_{1=1}^{n} Q_{c,i} = \sum_{i=1}^{n} Q_{l,i} + \mathrm{Q_{T,loss}}$$

Voltage limits

(5) $$V_{min} \le |V_i| \le V_{max}$$

(6) $1 \geq V_i \geq 0.9$

Compensation Constraint

(7) $Q_{MAX} \leq Q_{i,c} \leq Q_{MIN}$

(8) $\sum_{i=1}^{n} Q_{i,c} \leq \sum_{i=1}^{n} Q_{Li}$

Q_{Li}:reactive power of loads.

$Q_{i,c}$ reactive power of capacitors.

Power limits of the DGs

(9) $P_{MIN} \leq P_{i,n} \leq P_{MAX}$

(10) ∑_(i=1)^n▒P_(i,n) ≤∑_(i=1)^n▒P_Li

P_{Li}: active power of loads.

$P_{i,c}$:active power of distributed generation

2- 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, easy implementation, and ability to find optimal solutions efficiently[11]. Figure (1) illustrates the Basic bees algorithm[12].

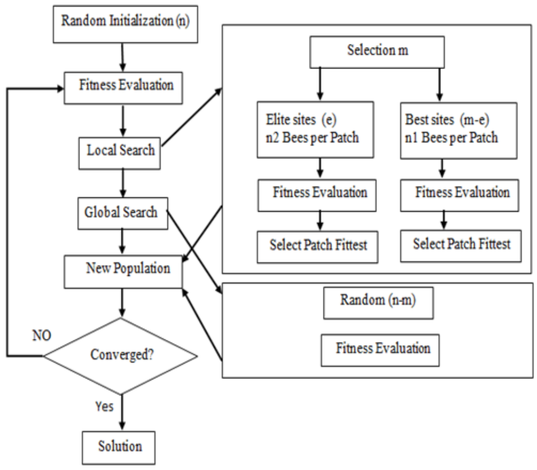

Fig 1 Flow chart of bees algorithm

Initially, the algorithm must be prepared with the following parameters [12].

Population sizing (number of scout bees, ns).

1- number of best sites, m.
2- number of elite sites, e.
3- Recruited bees for elite sites,n1
4- Recruited bees for (m-e) sites,n2
5- Initial size of neighbourhood,ngh
6- 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

3- JAYA Algorithm

Let f(x) is the objective function. At any iteration i, assume that there are 'p' number of design variables (i.e. j=1,2,…,p), 'c' number of candidate solutions (i.e. population size, k=1,2,…,c). Let the best candidate *best* obtains the best value of f(x) (i.e. f(x)best) in the entire candidate solutions, and the worst candidate worst obtains the *worst* value of f(x) (i.e. f(x)worst) in the entire candidate solutions [13]. If X^{i}_{j} is the current value, then this value is modified as per the following Eq. (11).[14]

$$X'^{i}_{j} = X^{i}_{j} + r1_j\left(X^{best}_{j} - \left|X^{i}_{j}\right|\right) - r2_j\left(X^{worst}_{j} - \left|X^{i}_{j}\right|\right) \quad (11)$$

where, X^{best}_{j} is the best solution and X^{worst}_{j} is the worst solution and r1,j and r2,j are the two random numbers in the range [0, 1]. The term "$\left(r1_j\left(X^{best}_{j} - \left|X^{i}_{j}\right|\right)\right)$" the solution to move closer to the best solution and the term "$r2_j\left(X^{worst}_{j} - \left|X^{i}_{j}\right|\right)$" indicates the solution to avoid the worst solution. $X'^{i}_{j}$is accepted if it gives better function value. All the accepted function values at the end of iteration are maintained, and these values become the input to the next iteration.

Fig.2 shows the flowchart of the JAYA algorithm. The algorithm always tries to get closer to success and tries to avoid failure [14]

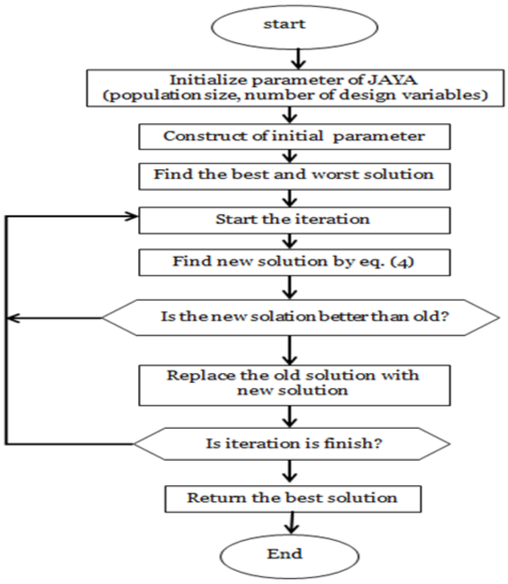

Fig 2 Flow chart of JAYA

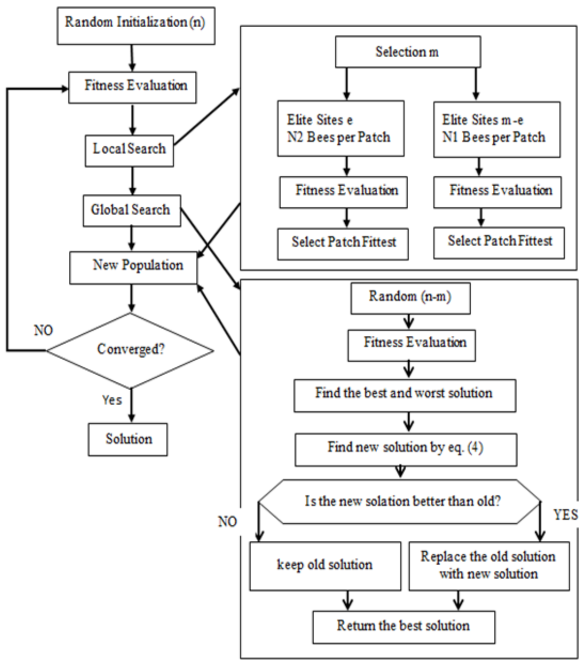

Fig 3 Flow chart Hybrid Algorithm

4- Hybrid Algorithm:

The bee algorithm is considered one of the important and essential algorithms in the field of improving the performance of electrical networks, due to its positive results in enhancing the performance of these electrical networks. However, one of the main problems faced by this algorithm is the easy of falling into the local solution problem Therefore, we proposed a solution to this problem by utilizing the JAYA algorithm to overcome this issue. In the basic bee algorithm, the global search was random. In contrast, in the hybrid algorithm, this issue was addressed by utilizing the high-performance speed of the JAYA algorithm in searching for the optimal solution. Applying this algorithm on standard networks showed superior performance compared to other algorithms, especially when integrating capacitors with distributed generation systems in radial electrical networks.

The different steps Hybrid algorithm are as follows:
1- Set the parameters of the bee algorithm: swarm size (N), maximum number of iterations, number of control variables, and variable bounds.
2- Assign random values to the control variables (capacitor, distributor generation locations, and sizing) within the appropriate constraints.
3- Find the objective function to minimize the total power losses then Sort the results in ascending orderand select the first value as the best solution.
4- Test a percentage of the best locations (m) out of N and send a number of worker bees (n1) to search around these locations randomly to find better locations within the given constraints. Then, find the objective function based on Backward Forward Sweep Algorithm.
5- Test a percentage of the select locations (e) out of m and send a number of worker bees (n2) to search around these locations randomly to find better locations within the given constraints. Then, find the objective function based on Backward Forward Sweep Algorithm.
6-Assign new random values to the remaining locations (m+1, n) and find the objective function for these newly assigned values by the JAYA algorithm. Finally, sort the results in ascending order and select the first value as the objective function.
7-Repeat steps 4 to 7 until the maximum number of iterations is done or until the objective function curve stabilizes, indicating the end of the optimization process.

5- Applications

5-1 Test distribution system

Hybrid algorithm algorithm is applied to IEEE 33 and IEEE69 .IEEE33 bus distributed system has 12.66 kv. The total real and reactive loads are 3.715 + j2.3 MVA and the total real power losses are 202.67 kW [15]. The power flow in IEEE 33-bus is calculated using Backward Forward Sweep. However ,IEEE69 bus distributed system has 12.66 kv. The total real and reactive loads are 3.801 + j2.694 MVA and the total real power losses are 224.95 kW. Also,The power flow in IEEE 69-bus is calculated using Backward Forward Sweep [15]

5-2 Cases studied

Case 1: power loss reduction with only CBs
Case 2: power loss reduction with only DG
Case 3: power loss reduction with combined DGs and CBs
We can finding Parameters setting of the bees algorithm in table 1

Table (1) Parameters setting of the bees algorithm

Max iteration	Recruited bees for elite sites,n1	Recruited bees for (m-e) sites,n2	fittest bees (m)	elite bees (e)	Population (n)
100	40	20	18	60	100

6- Rsults and comments

6-1 IEEE33 bus radial system

Case 1: power loss reduction with only CBs

We can see that the power loses reduce from 202.34 kw to 130.716kw ie 35.39%. this result is better from other reference . the total sizing of capacitor is 2067 kvar.

Table (2) results of case 1, IEEE33

Power losses kw	Sizing and location of capacitor MVAR	Algorithm
144.04	0.349(18), 0.821(30), 0.227(33)	[4] BFOA
131.5	0.6 (11), 0.3 (33), 0.45 (24), 0.6 (30)	[4] CSA
132.48	0.9 (2), 0.45 (7), 0.45 (31), 0.3 (15), 0.45 (29)	[4] PSO
130.912	0.3973 (14), 0.4511 (24), 1.0 (30)	[4] SSA
130.716	0.331(14),0.450(24),0.450(30), 0.450 (7),0.386(31)	Purpose method

Case 2: power loss reduction with only DG

We can see that the power loses reduce from 202.34 kw to 71.45 kw ie 64.68%. this result is better from other reference . the total sizing of DG is 2925 kw.

Table (3) results of case 2, IEEE33

Power losses KW	Sizing and location of DG MW	algorithm
88.68	0.5897 (14), 0.189 (18), 1.0146 (32)	[4] FWA
98.3	0.633 (17), 0.09 (18), 0.9470 (33)	[4] BFOA
96.76	0.5724 (17), 0.107 (18), 1.0462 (33)	[4] HSA
71.852	0.8546 (14), 1.1017 (24), 1.181 (29)	[4] SSA
71.456	0.754(14), 0.1071(30), 0.1100(24)	Purpose method

Case 3: power loss reduction with combined DGs and CBs

We can see that the power loses reduce from 202.34 kw to 11.71 kw ie 94.21%. this result is better from other reference . the total sizing of DG is 1833 kw. And sizing of capacitor is 2876 Mvar

Table (4) results of case 3, IEEE33

Power losses KW	Sizing and location of DG KW	Sizing and location of capacitor MVAR	algorithm
71.25	0.25 (16), 0.25 (22), 0.50 (30)	0.30 (15), 0.30 (18), 0.30 (29), 0.60 (30), 0.30 (31)	[4] GA
41.41	0.542(17), 0.160(18), 0.895(33)	0.163 (18), 0.338 (33), 0.541 (30),	[4] BOFA
24.688	0.973(25), 1.04(29), 0.563(11)	0.465 (23), 0.565 (30), 0.535 (14)	[4] SSA
11.7145	1051(30), 450 (24) , 332 (14)	1.049(30), 0.747 (14) 1.080 (24)	Purpose method

6-2 IEEE69 bus radial system

Case 1: power loss reduction with only CBs

We can see that the power loses reduce from 224.95 kw to 144.30kw ie 35.85%. this result is better from other reference . the total sizing of capacitor is 2284 kvar.

Table (5) results of case 1, IEEE69

Power losses kw	Sizing and location of (MVAR) capacitor	Algorithm
145.86	0.450(11), 1.350(61) 0.150(22)	FPA [5]
146.35	0.600(12),1.050(61), 0.150(64)	TLIB [5]
163.28	0.900(11), 1.050(29) 0.450(60)	IP [5]
148.91	0.225(19),0.900(62), 0.225(63)	Tow stage method [5]
144.3050	0.900(61),0.314(64), 0.319(66),0.450(50), 0.301(18))	Purpose method

Case 2: power loss reduction with only DG

We can see that the power loses reduce from 224.95 kw to 69.4077 kw ie 68.90 %. this result is better from other reference . the total sizing of DG is 2626 kw.

Table (6) results of case 2, IEEE69

Power losses KW	Sizing and location of DG MW	algorithm
77.85	1.8329	[15] FWA
88.5	1.9471	[15] GA
86.77	1.7732	[15] HSA
87.65	1.7868	[15] RGA
69.4077	2.626	Purpose method

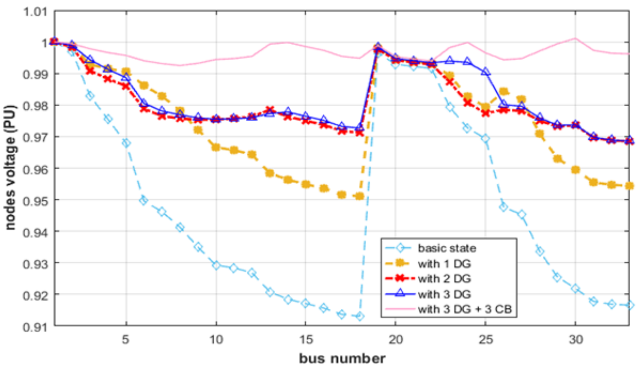

Fig 4 nodes voltage of IEEE33

Voltage profile has been improved as shown in figure 4

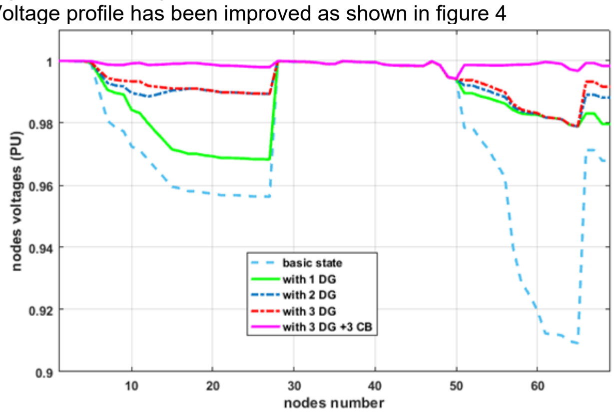

Fig. 5 nodes voltage of IEEE69

Case 3: power loss reduction with combined DGs and CBs

We can see that the power loses reduce from 224.95 kw to 4.33 kw ie 98.075%. . the total sizing of DG is 2547 kw. And sizing of capacitor is 1696 Kvar.

Voltage profile has been improved as shown in figure 4

7- Conclusion

We conclude that the proposed method (the bees algorithm and JAYA) gave the best results compare with other algorithms. This was achieved by finding the optimal location and capacity of capacitor and distributed generation installed in the studied network. The active losses in the IEEE33 , IEEE69 networks decreased by 94.21% , 98.07 % respectively when adding capacitor and distributed generation The voltage values in most of the studied network nodes were also improved

REFERENCES

[1] A. Keane, L.F. Ochoa, C.L.T. Borges, G.W. Ault, A.D. Alarcon Rodriguez, R.A.F. Currie, F. Pilo, C. Dent, G.P. Harrison, State-of-the-art techniques and challenges ahead for distributed generation planning and optimization, IEEE Trans. Power Syst. 28 (2013) 1493

[2] Hayes, B. (2017). Distribution Generation Optimization and Energy Management. Distributed Generation Systems; Gharehpetian, GB, Agah, SMM, Eds.; Elsevier Inc.: Oxford, UK, 415-451

[3] Kaya, A., & Bozkurt, A. (2021). "Determining optimum location and sizing of distributed generation systems in a real radial distribution network". Electrical, 21(3), 342-

[4] Dehghani, M., Montazeri, Z., & Malik, O. P. (2020). "Optimal sizing and placement of capacitor banks and distributed generation in distribution systems using spring search algorithm". International Journal of Emerging Electric Power .Systems, 21(1).

[5] Ogunsina, A. A., Petinrin, M. O., Petinrin, O. O., Offornedo, E. N., Petinrin, J. O., & Asaolu, G. O. (2021). "Optimal distributed generation location and sizing for loss minimization and voltage profile optimization using ant colony algorithm SN Applied Sciences, 3, 1-10.

[6] Uchendu, M. (2020)." Placement of distributed generation and shunt capacitor in distribution network using cuckoo search algorithm". Nigerian journal of technological development, 17(2), 79-87.

[7] Duong, M. Q., Pham, T. D., Nguyen, T. T., Doan, A. T., & Tran, H. V. (2019). Determination of optimal location and sizing of solar photovoltaic distribution generation units in radial distribution systems. Energies, 12(1).

[8] Khan, M. H., Ulasyar, A., Khattak, A., Zad, H. S., Alsharef, M., Alahmadi, A. A., & Ullah, N. (2022). Optimal Sizing and Allocation of Distributed Generation in the Radial Power Distribution System Using Honey Badger Algorithm. Energies, 15(16), 5891

[9] Okelola, M. O., Adebiyi, O. W., Salimon, S. A., Ayanlade, S. O., & Amoo, A. L. (2022). Optimal sizing and placement of shunt capacitors on the distribution system using whale optimization algorithm. Nigerian Journal of Technological Development, 19(1), 39-47

[10] Soma, G. G. (2021). Optimal sizing and placement of capacitor banks in distribution networks using a genetic algorithm. Electricity, 2(2), 187-204

[11] 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

[12] Castellani, M., Pham, D.T. (2023). The Bees Algorithm—A Gentle Introduction. In: Pham, D.T., Hartono, N. (eds) Intelligent Production and Manufacturing Optimisation—The Bees Algorithm Approach. Springer Series in Advanced Manufacturing. Springer, Cham.

[13] 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.

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

[15] Imran, A. M., Kowsalya, M., & Kothari, D. P. (2014). A novel integration technique for optimal network reconfiguration and distributed generation placement in power distribution networks. International Journal of Electrical Power & Energy Systems, 63, 461-472.