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Optimal size and location of distributed generations in distribution networks using bald eagle search algorithm

Introduction. *In the actual era, the integration of decentralized generation in radial distribution networks is becoming important for the reasons of their environmental and economic benefits.* ***Purpose.*** *This paper investigate the optimal size, location and kind of decentralized generation connected in radial distribution networks using a new optimization algorithm namely bald eagle search.* ***Methods.*** *The authors check the optimal allocation of two kinds of decentralized generation the first is operated at unity power factor and the second is operated at 0.95 power factor, a multi-objective functions are minimized based on reduction of voltage deviation index, active and reactive power losses, while taking into consideration several constraints.* ***Results.*** *Simulation results obtained on Standard IEEE-33 bus and IEEE-69 bus radial distribution networks demonstrate the performance and the efficiency of bald eagle search compared with the algorithms existing in literature and radial distribution networks performances are improved in terms of voltage profile and notably active and reactive power losses reduction, decentralized generation operated at 0.95 power factor are more perfect than those operated at unit power factor.* References 31, tables 4, figures 8.
Key words: **decentralized generation, radial distribution networks, bald eagle search algorithm, power losses, voltage profile.**

Вступ. *У сучасну епоху інтеграція децентралізованої генерації до радіальних розподільчих мереж стає важливою з причин їх екологічних та економічних переваг.* ***Мета***. *У цій статті досліджується оптимальний розмір, розташування та тип децентралізованої генерації, підключеної до радіальних розподільних мереж, з використанням нового алгоритму оптимізації, а саме пошуку білоголового орла.* ***Методи***. *Автори перевіряють оптимальне розподілення двох видів децентралізованої генерації, перший працює при коефіцієнті потужності, рівному одиниці, а другий працює при коефіцієнті потужності 0,95, мінімізується багатоцільова функція на основі зниження показника відхилення напруги, втрат активної та реактивної потужності, беручи до уваги кілька обмежень.* ***Результати***. *Результати моделювання, отримані на радіальних розподільних мережах стандартної шини IEEE-33 та шині IEEE-69, демонструють продуктивність та ефективність пошуку білоголового орлана в порівнянні з існуючими в літературі алгоритмами, а характеристики радіальних розподільчих мереж покращуються з точки зору профілю напруги та помітного зниження втрат активної та реактивної потужності, децентралізована генерація з коефіцієнтом потужності 0,95 більш досконала, ніж з одиничним коефіцієнтом потужності.* Бібл. 31, табл. 4, рис. 8.
Ключові слова: **децентралізована генерація, радіальні розподільчі мережі, алгоритм пошуку білоголового орла, втрати потужності, профіль напруги.**

1. Introduction. Previously generation and transmission power systems were responsible for the power quality transmitted to customers, but nowadays the close attention is distribution networks which are an easy target for electrical breakdowns [1]. The insertion of distributed generation (DGs) called decentralized generation; embedded generation, dispersed generation or on-site generation [2] into the radial distribution networks (RDNs) has attracted the attention of many researchers cause of their efficiency in improving voltage profile and decreasing power losses [3, 4]. DGs units can be divided into 2 types according to their resources, conventional such as diesel engines and renewable energies such as photovoltaic and wind turbine [5], and they can be divided into 4 groups according to the type of power supplied to RDNs:

- Group 1: DGs supply only active power;
- Group 2: DGs supply active and reactive power;
- Group 3: DGs supply active power and absorb reactive power;
- Group 4: DGs supply only reactive power [6].

Several studies have been carried out in literature with the main objective being to take advantage of benefits from connecting DGs to RDNs, either by optimizing the combination site and size, their location with specific capacity, their size with a defined site, their optimal size and site or specifying the correct type of DGs to be connected [7], without neglecting the permissible voltage limits which are RDNs nominal voltage plus ±5 % [8], because the integration of DGs units at inappropriate location with aleatory size may have adverse effects on RDNs power losses and voltage profile [9, 10].

Various algorithms have been used to study the optimal size and location of DGs where we mention next: Bat Optimization Algorithm (BA) [11], Water Cycle Algorithm (WCA) [12], Optimal Power Flow Algorithm (OPFA) [13], Slime Mould Algorithm (SMA) [14], Teaching Learning Combined with Harmony Search Algorithm (TLCHS) [15], Dragonfly Algorithm (DA) [16], Hybrid (WOA – SSA) Algorithm [17], Salp Swarm Algorithm (SSA) [18], Exchange Market Algorithm (EMA) [19], Fuzzy Logic Controller (FLC) [20], Fast Voltage Stability Index (FVSI), Whale Optimization Algorithm (WOA) [21], Genetic Algorithm (GA) [22, 23], Harris Hawks Optimization Algorithm (HHO) [24], Genetic Salp Swarm Algorithm (GA-SSA) [25], and Hybrid Firefly and Particle Swarm Optimization Algorithm (HFPSO) to find the optimal size of distributed generation and D-STATCOM [26].

The goal of the paper is checking the performance and the efficiency of the proposed bald eagle search (BES) algorithm compared to other algorithms existing in literature and compare the simulation results obtained by connecting distributed generation to radial distribution networks operating firstly at unity power factor and secondly at 0.95 power factor, on network performances such as voltage profile and reduction of active and reactive power losses.

The results are carried out on standard IEEE-33 bus and IEEE-69 bus test systems by reducing active and reactive power losses and voltage profile enhancement.

2. Problem formulation.

2.1 Objective function. The aim of this work is adapted to study the impact of the integration of DGs in

RDNs on active and reactive power losses and the voltage profile; therefore, the objective function can be described as:

Minimization of:

$$(F) = TPL + TQL + VDI\ , \tag{1}$$

where *TPL*, *TQL* and *VDI* are the total active power losses, total reactive power losses and voltage deviation index respectively:

$$TPL = \sum_{i=1}^{Nl} P_{loss}\ ; \tag{2}$$

$$P_{loss} = \left|I_{ij}\right|^2 \cdot R_{ij}\ ; \tag{3}$$

$$TQL = \sum_{i=1}^{Nl} Q_{loss}\ ; \tag{4}$$

$$Q_{loss} = \left|I_{ij}\right|^2 \cdot X_{ij}\ , \tag{5}$$

where *Nl* is the lines number; R_{ij} and X_{ij} are the resistance and reactance of *ij* line; I_{ij} is the current that flow from bus *i* to bus *j*;

$$VDI = \sum_{i=1}^{Nb} \left(1 - V_i\right)^2 , \tag{6}$$

where V_i is the voltage magnitude at i^{th} bus in p.u.; *Nb* is the number of busses.

2.2 Constraints.

$$P_{DG\min} \le P_{DG} \le P_{DG\max}\ ; \tag{7}$$

$P_{DG\min} = 0$ kW and $P_{DG\max} = 3000$ kW;

$$Q_{DG\min} \le Q_{DG} \le Q_{DG\max}\ ; \tag{8}$$

$Q_{DG\min} = 0$ kVAr and $Q_{DG\max} = 986$ kVAr;

$$\max\{S_{ij} \text{ or } S_{ji}\} \le S_{ij\max}\ ; \tag{9}$$

$$0.95 \le V_i \le 1.05\ ; \tag{10}$$

(i = 1 ... *Nb*);

where $P_{DG\max}$, $P_{DG\min}$ are the DGs generation active power limits; $Q_{DG\max}$, $Q_{DG\min}$ are the DGs generation reactive power limits; P_{DG}, Q_{DG} are DGs active and reactive power; S_{ij} and S_{ji} are the apparent power that flow from bus *i* to bus *j* or from bus *j* to *i*; $S_{ij\max}$ is the maximum apparent power flow in ij^{th} branch; V_i is the voltage magnitude at the i^{th} bus.

DGs can be connected at all busses except the substation bus.

$$2 \le DG_{Location} \le Nb\ , \tag{11}$$

$DG_{Location}$ is the bus where the DG can be connected; N_{DG} is the number of DGs installed in RDN (= 3).

3. Bald Eagle Search Algorithm. In 2020 H.A. Alsattar et al [27] developed a novel meta-heuristic Bald Eagle Search (BES) optimization algorithm, which mimics the behaviour of bald eagles during the hunt, bald eagles often hunt from perches but they can also hunt in flight and they are able to locate fish at great distances because it is difficult to catch the fish in water.

When the bald eagles start searching for the prey on a water spot, these hunters fly off in a specific direction and select a certain space to start the hunt. Consequently, this algorithm was divided into 3 stages and Fig. 1 exhibits the main steps of BES.

3.1 Select stage. In the select stage, bald eagles select the favourable search space (in terms of food quantity) where they can hunt prey (Fig. 2).

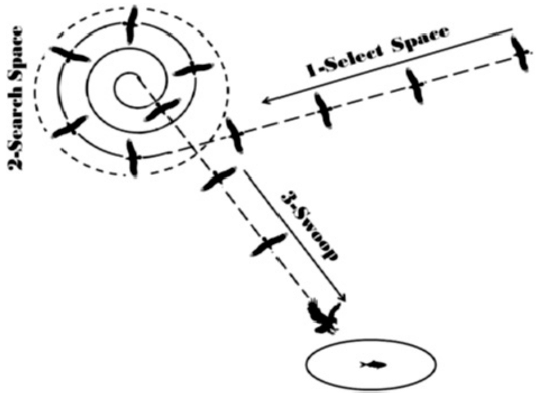

Fig. 1. Different steps of BES

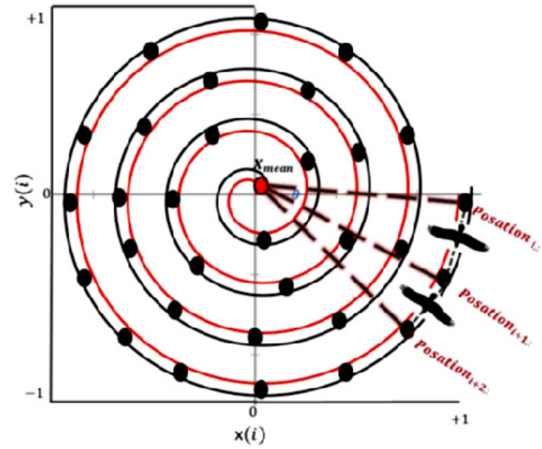

Fig. 2. Bald Eagles Searching within a spiral space

The bald eagles behaviour is presented in (12):

$$P_{new,i} = P_{best} + \alpha \cdot r\left(P_{mean} - P_i\right), \tag{12}$$

where α is the element that controls the position changes and it is in range of 1.5 to 2; *r* is the random number within [0, 1]; P_{best} is the best position identified by bald eagles during their previous search; P_{mean} indicates that the eagles have used all information from the previous points; P_i is the old eagle position and $P_{new,i}$ is the new position.

3.2 Search stage. In this stage, the eagles search for fish within the chosen search space and move within a spiral sense to accelerate their search.

The best position for the swoop is expressed by (13):

$$P_{new,i} = P_i + y(i) * \left(P_i - P_{i+1}\right) + x(i) * (P_i - P_{mean})\ ; \tag{13}$$

$$x(i) = \frac{xr(i)}{\left(\max\left|xr\right|\right)}; \tag{14}$$

$$y(i) = \frac{yr(i)}{\left(\max\left|yr\right|\right)}; \tag{15}$$

$$xr(i) = r(i) \cdot \sin(\theta(i))\ ; \tag{16}$$

$$yr(i) = r(i) \cdot \cos(\theta(i))\ ; \tag{17}$$

$$\theta(i) = \alpha \cdot \pi \cdot rand\ ; \tag{18}$$

$$r(i) = \theta(i) + R \cdot rand\ , \tag{19}$$

where α is the parameter which is in range of 5 to 10 for determining the corner between point search in the central point, and *R* takes a value between 0.5 and 2 for defining the number of search cycles and rand is the number within [0, 1].

3.3 Swooping stage. The bald eagles swooping from the best position in the search space to their target fish, all points move towards the best point. This behaviour is illustrated in (20):

$$P_{new,i} = rand \cdot P_{best} + x1(i) \cdot (P_i - C1 \cdot P_{mean}) + \\ + y1(i) \cdot (P_i - C2 \cdot P_{best}); \quad (20)$$

$$x1(i) = \frac{xr(i)}{(\max|xr|)}; \quad (21)$$

$$y1(i) = \frac{yr(i)}{(\max|yr|)}; \quad (22)$$

$$xr(i) = r(i) \cdot \sinh(\theta(i)); \quad (23)$$

$$yr(i) = r(i) \cdot \cosh(\theta(i)); \quad (24)$$

$$\theta(i) = \alpha \cdot \pi \cdot rand; \quad (25)$$

$$r(i) = \theta(i), \quad (26)$$

where $C1$, $C2 \in [1, 2]$ and *rand* is the number within [0, 1].

3.4 BES pseudo code.

Algorithm 1 Pseudo-Code of BES algorithm
1: Randomly initialize point P_i for n point; 2: Calculate the fitness values of initial point: $f(P_i)$; 3: WHILE (the termination conditions are not met) Select space 4: For (each point i in the population) 5: $P_{new} = P_{best} + \alpha \cdot \text{rand}(P_{mean} - P_i)$ 6: if $f(P_{new}) < f(P_i)$ 7: $P_i = P_{new}$ 8: if $f(P_{new}) < f(P_{best})$ 9: $P_{best} = P_{new}$ 10: End If 11: End If 12: End For Search in space 13: For (each point i in the population) 14: $P_{new} = P_i + y(i) \cdot (P_i - P_{i+1}) + x(i) \cdot P_i - P_{mean})$ 15: if $f(P_{new}) < f(P_i)$ 16: $P_i = P_{new}$ 17: if $f(P_{new}) < f(P_{best})$ 18: $P_{best} = P_{new}$ 19: End If 20: End If 21: End For Swoop 22: For (each point i in the population) 23: $P_{new} = \text{rand} \cdot P_{best} + x1(i) \cdot (P_i - \text{c}1 \cdot P_{mean}) +$ $+ y1(i) \cdot (P_i - \text{c}2 \cdot P_{best})$ 24: if $f(P_{new}) < f(P_i)$ 25: $P_i = P_{new}$ 26: if $f(P_{new}) < f(P_{best})$ 27: $P_{best} = P_{new}$ 28: End If 29: End If 30: End For 31: Set $k = k+1$; 32:END WHILE

4. Results and discussion. In this section improvement of voltage profile and reducing power losses are the mains objectives of the integration of DGs in RDNs. Backward / forward sweep based load flow has been chosen for load flow studies.

BES algorithm bio inspired algorithm is used for the optimization of the chosen objective function, and it is developed using MATLAB.

The simulation study was performed on: a PC with Intel (R) Core (TM) 2 Duo CPU t6570, 2.10 GHz, and 3.00 GB RAM.

The first studied system is IEEE-33 bus radial distribution network which has 33 bus, and 32 lines with total load of 3715 kW and 2300 kVAr [28].

The second studied system is IEEE-69 bus radial system which contains 69 bus, and 68 branches with total load of 3801, 39 kW and 2693 kVAr [28].

To check if the BES algorithm had given a perfect solution or not, a comparative study has been made with other well-known optimization algorithms.

BES algorithm was set with 100 of the population and 150 of maximum iterations as parameters setting values.

Three cases have been considered in the systems which are:

1. Base case (without DG).
2. Injecting of 3 DGs with unity p.f.
3. Injecting of 3 DGs with 0.95 p.f.

The base values are taken as 100 MVA and 12, 66 kV.

4.1 IEEE-33 bus distribution system. The first test system is standard IEEE-33 bus, which is depicted in Fig. 3.

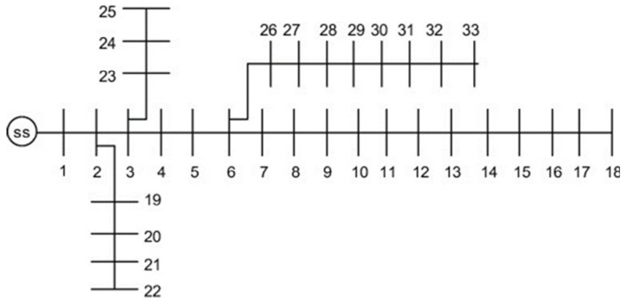

Fig. 3. IEEE-33 bus radial system single line diagram

In the base case the system fed only from the grid through the bus 1 (without DG) and the voltage profile curve per bus, displayed in Fig. 4 showed that the voltage magnitude at many busses is less than the minimum acceptable voltage (0.95 p.u.) and the lowest voltage is 0.9042 p.u. at bus 18, the simulation results indicate that the voltage deviation index is 3.2318 p.u., total active power losses 210.0534 kW and total reactive power losses 142.4354 kVAr.

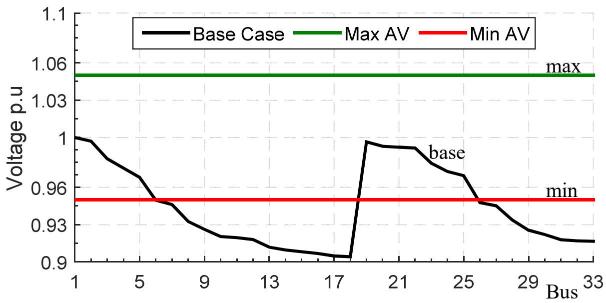

Fig. 4. Voltage profile IEEE-33 bus base case
max AV = 1.05 p.u. and min AV = 0.95 p.u.
are maximum and minimum acceptable voltages

The results at unity power factor presented in Table 1 and shows that the optimal locations and sizes obtained by BES algorithm reduces the active power losses to 70.64 kW, reactive power losses to 49.2659 kVAr and VDI to 0.2973 p.u.

Furthermore, the results at 0.95 power factor are performed and they are presented in Table 2, where the active power losses reach 27.859 kW, reactive power losses 20.7192 kVAr and VDI 0.0451 p.u.

Table 1
Optimal DG location for IEEE-33 bus test system at unity p.f.

Method	Optimal DG		TPL	VDI
	Bus	Size kW	kW	p.u.
MOHHO [5]	13 25 31	1207.0 763.0 1400.0	92.95	0.0020
MOIHHO [5]	14 24 31	1223.0 1144.0 1290.0	92.25	0.0019
GA [29]	11 29 30	1500.0 422.8 1071.4	106.30	0.0407
PSO [29]	08 13 32	1176.8 981.6 829.7	105.30	0.0335
GA/PSO [29]	11 16 32	925.0 863.0 1200.0	103.40	0.0124
TLBO [30]	12 28 30	1182.6 1191.3 1186.3	124.70	0.0011
QOTLBO [30]	13 26 33	1083.4 1187.6 1199.2	103.40	0.0011
BES	14 24 30	784.71 1053.8 1083.0	70.64	0.2973

Table 2
Optimal DG location for IEEE-33 bus test system at 0.95 p.f.

Method	Optimal DG			TPL	VDI
	Bus	Size		kW	p.u
		kW	kVAr		
MOHHO [5]	13 25 30	1008.0 910.0 1334.0	331.0 299.0 439.0	31.4	0.0005
MOIHHO [5]	13 24 30	924.0 1312.4 1356.0	304.0 431.0 446.0	30.6	0.0004
SIMBO-Q [31]	13 24 30	943.0 1327.0 1443.0	309.0 436.0 474.0	32.4	0.0003
QOSIMBO-Q [31]	13 24 30	898.0 1392.0 1419.0	295.0 458.0 467.0	31.7	0.0003
BES	13 24 30	840.41 1096.4 1234.1	276.23 360.38 405.63	27.6357	0.0445

From Fig. 5 it is clear that the voltage profile is improved at the 2 cases, but integration of DGs at 0.95 power factor is more convenient than at unity power factor.

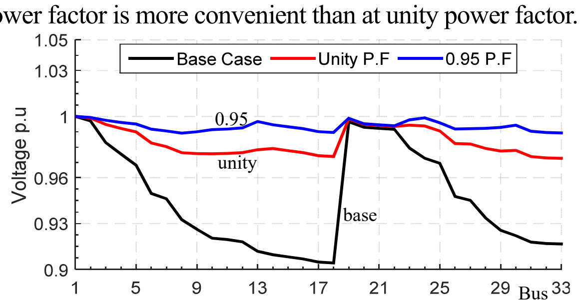

Fig. 5. Voltage profile curve IEEE 33 bus at the studied cases

Compared to other reviewed literatures this algorithm resulted a high reduction in terms of active and reactive power losses but not for the VDI.

4.2 IEEE-69 bus radial system. The second test system is IEEE-69 bus, which is presented in Fig. 6.

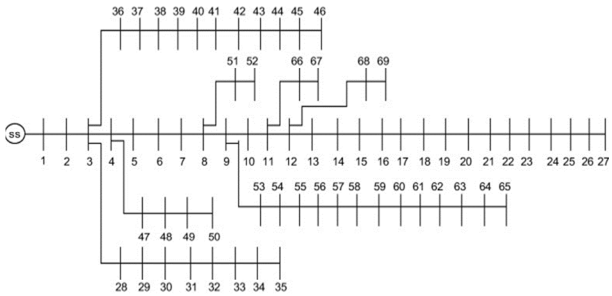

Fig. 6. IEEE-69 bus radial system single line diagram

In the base case the simulation results were carried out without DG and the voltage profile curve per bus figured in Fig. 7 showed that the magnitude voltage at many busses is less than the minimum acceptable voltage (0.95 p.u) and the lowest voltage is 0.9102 p.u. at bus 65.

The obtained results are as follows: voltage deviation index 3.3242 p.u., total active power losses 224.5533 kW and 101.9725 kVAr for the total reactive power losses.

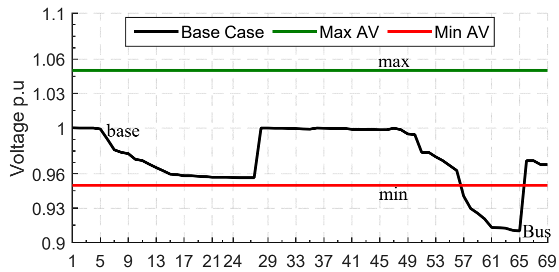

Fig. 7. Voltage profile IEEE-69 bus base case
max AV = 1.05 p.u. and min AV = 0.95 p.u.
are maximum and minimum acceptable voltages

Table 3 summarised the simulation results at unity power factor in this case the optimal locations and sizes obtained by BES algorithm reduced the active power losses to 68.9347 kW, reactive power losses to 31.6214 kVAr and VDI to 0.1689 p.u.

Table 3
Optimal DG location for IEEE-69 bus test system at unity p.f.

Method	Optimal DG		TPL	VDI
	Bus	Size kW	kW	p.u.
MOHHO [5]	20 60 61	643.6 763.4 1328.2	81.00	0.0008
MOIHHO [5]	18 61 64	796.2 1447.1 707.5	80.88	0.0007
GA [29]	21 62 64	929.7 1075.2 984.8	89.00	0.0012
PSO [29]	17 61 63	992.5 1199.8 795.6	83.20	0.0049
GA/PSO [29]	21 61 63	910.5 1192.6 1200.0	81.1	0.0031
TLBO [30]	13 61 62	1013.4 990.1 1160.1	82.2	0.0008
QOTLBO [30]	15 61 63	811.4 1147.0 1002.2	80.6	0.0007
BES	17 50 61	537.07 720.21 1805.6	68.94	0.1689

The results at 0.95 power factor presented in Table 4 were as follows the active power losses equal to 21.1609 kW, reactive power losses 9.8564 kVAr and VDI 0.0174 p.u.

Table 4

Optimal DG location for IEEE-69 bus test system at 0.95 p.f.

Method	Optimal DG			TPL	VDI
	Bus	Size		kW	p.u
		kW	kVAr		
MOHHO [5]	23 60 62	519.0 1176.0 1179.0	171.0 387.0 387.0	30.2	0.0010
MOIHHO[5]	13 61 63	1038.0 799.0 1229.0	341.0 263.0 404.0	28.9	0.0003
SIMBO-Q [31]	13 59 62	953.0 1002.0 1121.0	313.0 329.0 369.0	29.7	0.0003
QOSIMBO-Q [31]	17 56 63	487.0 1260.0 1500.0	160.0 414.0 493.0	31.4	0.0002
BES	17 50 61	586.64 802.38 1955.5	192.82 263.72 642.73	21.16	0.0174

From Fig. 8 it is clear that the voltage profile is improved at the 2 cases, but integration of DGs at 0.95 power factor is more efficient.

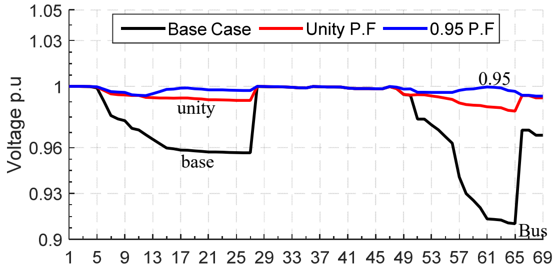

Fig. 8. Voltage profile curve IEEE-69 bus at the studied cases

Compared to other reviewed literatures this algorithm resulted a high effectiveness in terms of active and reactive power losses but not for the VDI.

Conclusions.

In this paper bald eagle search algorithm is used to investigate the optimal size and location of multiple decentralized generation with multi-objective functions (total active power losses, total reactive power losses and voltage deviation index). The bald eagle search algorithm has been assessed in standard IEEE-33 bus and 69 bus test systems.

The results obtained by bald eagle search algorithm showed a significant reduction of power losses as well as the improvement of voltage profile, and indicated that the case where distributed generation are operated at 0.95 power factor is more practical than the case where distributed generation are operated at unity power factor.

However, the comparison of simulation results with those existing in literature confirm the performance and the efficiency of this algorithm in terms of reducing power losses and little bit less concerning voltage deviation index.

Conflict of interest. The authors declare no conflict of interest.

REFERENCES

1. Gopal Reddy S., Ganapathy S., Manikandan M. Power quality improvement in distribution system based on dynamic voltage restorer using PI tuned fuzzy logic controller. *Electrical Engineering & Electromechanics*, 2022, no. 1, pp. 44-50. doi: https://doi.org/10.20998/2074-272X.2022.1.06.

2. Labed D. Production Decentralisée et Couplage au Réseau. *PhD Thesis. Department of Electrical Engineering University Frères Mentouri*, 2008, 173 p. (Fra).

3. M'hamdi B., Teguar M., Tahar B. Optimal DG Unit Placement and Sizing in Radial Distribution Network for Power Loss Minimization and Voltage Stability Enhancement. *Periodica Polytechnica Electrical Engineering and Computer Science*, 2020, vol. 64, no. 2, pp. 157-169. doi: https://doi.org/10.3311/PPee.15057.

4. Bouraghda S., Sebaa K., Bechouat M., Sedraoui M. An improved sliding mode control for reduction of harmonic currents in grid system connected with a wind turbine equipped by a doubly-fed induction generator. *Electrical Engineering & Electromechanics*, 2022, no. 2, pp. 47-55. doi: https://doi.org/10.20998/2074-272X.2022.2.08.

5. Selim A., Kamel S., Alghamdi A.S., Jurado F. Optimal Placement of DGs in Distribution System Using an Improved Harris Hawks Optimizer Based on Single- and Multi-Objective Approaches. *IEEE Access*, 2020, vol. 8, pp. 52815-52829. doi: https://doi.org/10.1109/ACCESS.2020.2980245.

6. Noureddine T., Djamel L. Load flow analysis using newton raphson method in presence of distributed generation. *International Journal of Power Electronics and Drive Systems (IJPEDS)*, 2021, vol. 12, no. 1, pp. 489-498. doi: https://doi.org/10.11591/ijpeds.v12.i1.pp489-498.

7. Ouali S., Cherkaoui A. Optimal Allocation of Combined Renewable Distributed Generation and Capacitor Units for Interconnection Cost Reduction. *Journal of Electrical and Computer Engineering*, 2020, pp. 1-11. doi: https://doi.org/10.1155/2020/5101387.

8. Raj A., Aziz N.F.A., Yasin Z.M., Salim N.A. Investigation of distributed generation units placement and sizing based on voltage stability condition indicator (VSCI). *International Journal of Power Electronics and Drive Systems (IJPEDS)*, 2019, vol. 10, no. 3, pp. 1317-1323. doi: https://doi.org/10.11591/ijpeds.v10.i3.pp1317-1323.

9. Sa'ed J.A., Quraan M., Samara Q., Favuzza S., Zizzo G. Impact of integrating photovoltaic based DG on distribution network harmonics. *2017 IEEE International Conference on Environment and Electrical Engineering and 2017 IEEE Industrial and Commercial Power Systems Europe (EEEIC / I&CPS Europe)*, 2017, pp. 1-5. doi: https://doi.org/10.1109/EEEIC.2017.7977786.

10. Kyryk V.V., Bohomolova O.S. Justification of optimal location of connection of the distributed generation source and value of its power. *Electrical Engineering & Electromechanics*, 2019, no. 2, pp. 55-60. doi: https://doi.org/10.20998/2074-272X.2019.2.08.

11. Yuvaraj T., Devabalaji K.R., Ravi K. Optimal Allocation of DG in the Radial Distribution Network Using Bat Optimization Algorithm. In: Garg, A., Bhoi, A., Sanjeevikumar, P., Kamani, K. (eds) *Advances in Power Systems and Energy Management. Lecture Notes in Electrical Engineering*, 2018, vol. 436. Springer, Singapore. doi: https://doi.org/10.1007/978-981-10-4394-9_55.

12. El-Ela A.A.A., El-Sehiemy R.A., Abbas A.S. Optimal Placement and Sizing of Distributed Generation and Capacitor Banks in Distribution Systems Using Water Cycle Algorithm. *IEEE Systems Journal*, 2018, vol. 12, no. 4, pp. 3629-3636. doi: https://doi.org/10.1109/JSYST.2018.2796847.

13. Singh B., Gyanish B.J. Impact assessment of DG in distribution systems from minimization of total real power loss viewpoint by using optimal power flow algorithms. *Energy Reports*, 2018, vol. 4, pp. 407-417. doi: https://doi.org/10.1016/j.egyr.2018.07.003.

14. Kouadri R., Slimani L., Bouktir T. Slime mould algorithm for practical optimal power flow solutions incorporating stochastic wind power and static var compensator device. *Electrical Engineering & Electromechanics*, 2020, no. 6, pp. 45-54. doi: https://doi.org/10.20998/2074-272X.2020.6.07.

15. Alam A., Zaheer B., Zaid M. Optimal Placement of DG in Distribution System for Power Loss Minimization and Voltage Profile Improvement. *2018 International Conference on Computing, Power and Communication Technologies (GUCON)*, 2018, pp. 837-842. doi: https://doi.org/10.1109/GUCON.2018.8674930.
16. Suresh M.C.V., Belwin E.J. Optimal DG placement for benefit maximization in distribution networks by using Dragonfly algorithm. *Renewables: Wind, Water, and Solar*, 2018, vol. 5, no. 1, art. no. 4. doi: https://doi.org/10.1186/s40807-018-0050-7.
17. Alzaidi K.M.S., Bayat O., Uçan O.N. Multiple DGs for Reducing Total Power Losses in Radial Distribution Systems Using Hybrid WOA-SSA Algorithm. *International Journal of Photoenergy*, 2019, pp. 1-20. doi: https://doi.org/10.1155/2019/2426538.
18. Sambaiah K.S., Jayabarathi T. Optimal Allocation of Renewable Distributed Generation and Capacitor Banks in Distribution Systems using Salp Swarm Algorithm. *International Journal of Renewable Energy Research*, 2019, vol. 9, no. 1, pp. 96-107. doi: https://doi.org/10.20508/ijrer.v9i1.8581.g7567.
19. Daneshvar M., Abapour M., Mohammadi-ivatloo B., Asadi S. Impact of Optimal DG Placement and Sizing on Power Reliability and Voltage Profile of Radial Distribution Networks. *Majlesi Journal of Electrical Engineering*, 2019, vol. 13, no. 2, pp. 91-102. Available at: http://mjee.iaumajlesi.ac.ir/index/index.php/ee/article/view/2782 (Accessed 10 May 2022).
20. Kumar Sharma S., K. Palwalia D., Shrivastava V. Distributed generation integration optimization using fuzzy logic controller. *AIMS Energy*, 2019, vol. 7, no. 3, pp. 337-348. doi: https://doi.org/10.3934/energy.2019.3.337.
21. Ang S., Leeton U. Optimal placement and size of distributed generation in radial distribution system using whale optimization algorithm. *Suranaree Journal of Science and Technology*, 2019, vol. 26, no. 1, pp. 1-12. Available at: https://ird.sut.ac.th/e-journal/Journal/pdf/180101220.pdf (Accessed 10 May 2022).
22. Bawa A., Uthman M., Shaibu F.E., Oyewale K.S. Optimal Sizing and Sitting of Distributed Generation for Power Quality Improvement of Distribution Network. *European Journal of Engineering and Technology Research*, 2019, vol. 4, no. 10, pp. 18-23. doi: https://doi.org/10.24018/ejeng.2019.4.10.1555.
23. Prakash S., Rangta V., Jayalakshmi N.S., Kumar Jadoun V. Optimal Location of DGs in a Distribution System for Maintaining Voltage Profile and Loss Reduction Using Genetic Algorithm. *2020 International Conference on Power Electronics & IoT Applications in Renewable Energy and Its Control (PARC)*, 2020, pp. 59-64. doi: https://doi.org/10.1109/PARC49193.2020.236558.
24. Islam M.Z., Wahab N.I.A., Veerasamy V., Hizam H., Mailah N.F., Guerrero J.M., Mohd Nasir M.N. A Harris Hawks Optimization Based Single- and Multi-Objective Optimal Power Flow Considering Environmental Emission. *Sustainability*, 2020, vol. 12, no. 13, art. no. 5248. doi: https://doi.org/10.3390/su12135248.
25. Djabali C., Bouktir T. Simultaneous allocation of multiple distributed generation and capacitors in radial network using genetic-salp swarm algorithm. *Electrical Engineering & Electromechanics*, 2020, no. 4, pp. 59-66. doi: https://doi.org/10.20998/2074-272X.2020.4.08.
26. Mohsin Al-Wazni H.S., Abdulla Al-Kubragyi S.S. A hybrid algorithm for voltage stability enhancement of distribution systems. *International Journal of Electrical and Computer Engineering (IJECE)*, 2022, vol. 12, no. 1, pp. 50-61. doi: https://doi.org/10.11591/ijece.v12i1.pp50-61.
27. Alsattar H.A., Zaidan A.A., Zaidan B.B. Novel meta-heuristic bald eagle search optimisation algorithm. *Artificial Intelligence Review*, 2020, vol. 53, no. 3, pp. 2237-2264. doi: https://doi.org/10.1007/s10462-019-09732-5.
28. Aguirre-Angulo B.E., Giraldo-Bello L.C., Montoya O.D., Moya F.D. Optimal Integration of Dispersed Generation in Medium-Voltage Distribution Networks for Voltage Stability Enhancement. *Algorithms*, 2022, vol. 15, no. 2, art. no. 37. doi: https://doi.org/10.3390/a15020037.
29. Moradi M.H., Abedini M. A combination of genetic algorithm and particle swarm optimization for optimal DG location and sizing in distribution systems. *International Journal of Electrical Power & Energy Systems*, 2012, vol. 34, no. 1, pp. 66-74. doi: https://doi.org/10.1016/j.ijepes.2011.08.023.
30. Sultana S., Roy P.K. Multi-objective quasi-oppositional teaching learning based optimization for optimal location of distributed generator in radial distribution systems. *International Journal of Electrical Power & Energy Systems*, 2014, vol. 63, pp. 534-545. doi: https://doi.org/10.1016/j.ijepes.2014.06.031.
31. Sharma S., Bhattacharjee S., Bhattacharya A. Quasi-Oppositional Swine Influenza Model Based Optimization with Quarantine for optimal allocation of DG in radial distribution network. *International Journal of Electrical Power & Energy Systems*, 2016, vol. 74, pp. 348-373. doi: https://doi.org/10.1016/j.ijepes.2015.07.034.

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