Mustafa Mosbah[1], Rabie Zine[2*], Salem Arif[1], Ridha d. Mohammedi[3]

J. Electrical Systems 14-4 (2018): 180-189

Regular paper

Optimum Distribution Network Reconfiguration in Presence DG Unit Using BBO Algorithm

JES Journal of Electrical Systems

The power electrical distribution network have a very weakly meshed reconfiguration, with loops between different source stations, but the operation is carried out via a tree-based reconfiguration. This reconfiguration is determined by the closing and opening of switches device in objective to optimize the total real losses in consideration of the technical and topological distribution network constraints. In this paper, a Biogeography Based Optimization (BBO) method based on graphs theory is proposed to search an optimal reconfiguration in presence of a distributed generation unit. The proposed method is tested on different types of IEEE distribution networks (33bus, 69bus, 84bus) and validated on Algerian distribution network (116bus). The proposed method was developed under MATLAB software.

Keywords: Radial network; reconfiguration; graph theory; active losses; BBO optimization.

Article history: Received 25 March 2018, Accepted 3 November 2018

1. Introduction

Power Electrical Distribution Network (PEDN) represent a very important element in the supply chain of power system. The PEDN are operated according to an arboreal reconfiguration [1]. The PEDN reconfiguration is changing in distribution system topology, by using the switches state (open state/closed state) of such a spell to balance the loads, and/or minimizing power losses and/or improving voltage plan and/or improving the service quality and service continuity, while satisfying technical and topological PEDN constraints [2,3]. The PEDN reconfiguration imposes a non-linear, discrete variables nature, constrained optimisation, complex combinatorial and NP-hard problem which requires the use of a robust optimization technique [4].

Several deterministic algorithms have been proposed in literature to find the optimal PEDN reconfiguration, for instance, Simplex Method has been proposed by paper [5] to determine the optimal reconfiguration minimizing the lines length under different constraints. The authors of [6] proposed the same Simplex technique with a fitness function which minimizes active power losses. A Spanning Tree Method based the Kruskal algorithm was applied to minimize active losses taking into account technical and topological constraints [7]. Minimum losses network reconfiguration using Mixed-Integer Convex Programming Method [8].

Several methods using metaheuristic, artificial intelligence have been applied to find the optimal PEDN reconfiguration in particular cases, see for instance, [9-22].

The main results in this paper, is to use the BBO to search an optimal reconfiguration in presence of a distributed generation unit. The following algorithm is tested on several types

[*] Corresponding author: R. Zine, E-mail: rabie.zine@gmail.com

[1] LACoSERE Laboratory, Department of Electrical Engineering, Amar Telidji University of Laghouat, Algeria.

[2] Department of Mathematics, Faculty of Sciences and Humanities, Aflaj, Prince Sattam Bin Abdulaziz University, Saudi Arabia.

[3] Faculty of Electrical Engineering, University Djelfa, Djelfa 17000, Algeria.

of IEEE distribution networks (33bus, 69bus and 84bus) and validated on Algerian PEDN (116bus). The proposed method was developed under MATLAB 2015a.

2. Mathematical formulation Problem

2.1. Objective function

Losses are one of vigorous amounts in a PEDN that why they are chosen as objective function to keep them as low as possible for better service of the network. A starting bus is powering one receiving bus in a PEDN. Example distribution line with switches device is presented by following figure.

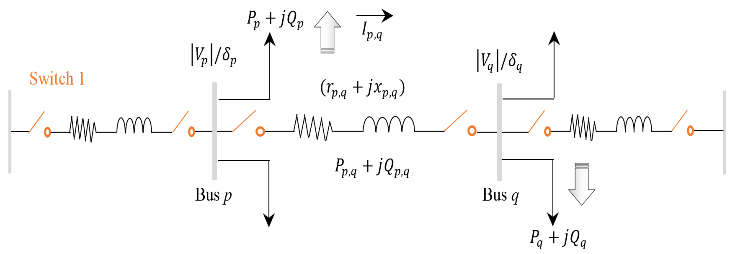

Fig. 1. Example distribution line between bus p and bus q in presence switches device

$$P_{loss}^{T} = I_{pq}^{2} R_{pq} = \frac{S_{pq}^{2}}{V_{p}^{2}} R_{pq} = \frac{P_{pq}^{2} + Q_{pq}^{2}}{V_{p}^{2}} R_{pq} \tag{1}$$

$$F = Min \sum_{i=1}^{NB} P_{loss(i)} \tag{2}$$

where $|V_p| / \delta_p$ is voltage magnitude at bus p, r_{pq} and x_{pq} are resistance and reactance of line between bus p and q, respectively, P_{pq} and Q_{pq} are active and reactive power through the branch between bus p and q, NB is number of branches and N is number of bus network.

2.1. Topological constraints

- The connectivity: All buses in distribution network needs to be connected by some line (no isolated nodes).
- The radiality: PEDN configuration is connected and without loop (radial topology).

2.2. Equality constraints

Represents the power balance constraints considering the distributed generation including a non-linear recursive power flow equations

$$\begin{cases} \sum_{i=1}^{N_G} P_G + \sum_{i=1}^{N_{DG}} P_{DG} - \sum_{i=1}^{N_L} P_D - \sum_{i=1}^{NB} P_{loss} = 0 \\ \sum_{i=1}^{N_G} Q_G + \sum_{i=1}^{N_{DG}} Q_{DG} - \sum_{i=1}^{N_L} Q_D - \sum_{i=1}^{NB} Q_{loss} = 0 \end{cases} \quad (3)$$

where (P_G, Q_G) are total active and reactive power of generator, respectively, (P_D, Q_D) are total active and reactive power of load, respectively, (P_{loss}, Q_{loss}) are total active and reactive power losses respectively, and (P_{DG}, Q_{DG}) are active and reactive power of distributed generation. N_L, N_G, N, NB and N_{DG} are number of loads bus, number of conventional generators, number of all buses, number of branches and number of distributed generation, respectively.

2.3. Inequality constraints

In distribution network, the voltage must be kept within the standard limits of each bus and it may mathematically be expressed as:

$$V_{imin} \le V_i \le V_{imax} \quad for\, i = 1\ldots\ldots N \quad (4)$$

The rating of each branch is constrained by its permissible power as:

$$S_{li} \le S_{limax} \quad for\ i = 1\ldots\ldots NB \quad (5)$$

Upper and lower real power generation limits of conventional generator at bus *i*, are expressed as:

$$P_{Gimin} \le P_{Gi} \le P_{Gimax} \ for \quad i = 1\ldots\ldots N_G \quad (6)$$

Distributed generation limit includes the lower and upper active power generation limits of total active load, which can be expressed as:

$$0 \le \sum_{i=1}^{N_{DG}} P_{DGi} \le 0.3 \times \sum_{i=1}^{N} P_{Di} \quad for\, i = 1\ldots\ldots N_{DG} \quad (7)$$

2.4. Maintaining solution feasibility

The strategist reservation feasibility is used to generated the control variables in their permissible limits. The optimization problem is then transformed from a problem with constraints into a problem without constraints to ease dealing with [34-36], the equation (2) can be then changed by:

$$\min\ F = \sum_{i=1}^{NB} P_{loss(i)} + k_v \left(V_{Li} - V_{Li}^{\lim} \right)^2 + k_s \left(S_{li} - S_{li}^{\lim} \right)^2 + k_m N_m + k_i N_i \quad (8)$$

where k_v, k_s, k_m and k_i are penalty factors, N_m is the number of existing meshes, N_i is the number of isolated loads.

In this study, the values of penalty factors have been considered 10.000, it should be noted that the addition of penalty factors following the violation constraints.

3. Applied Approach

In the last years several engineering domains are more and more focused on optimization algorithm biogeography, especially in electrical engineering applications. This algorithem has proved its effectiveness in comparison with other methods [37]. The BBO algorithm is basically stimulated from the theory of island biogeography. A detailed explanation of BBO can be found in [38]. The optimization based in the biogeography is one of the most recent stochastic optimization algorithms. It's based on species motion for living islands between ecosystems. BBO optimization uses similar vocabulary to the one of biogeography where each living islands is a solution for the problem. Solutions characteristic are named Suitability Index Variable (*SIV*). Habitat Suitability Index (*HSI*) is analog to fitness that allow to measure adequate individual. The habitats with a higher *HSI* are tend to have a big number of species, an immigration amount low and a high emigration amount. Conversely, the habitats with a lower *HSI* are tend to have less number of species, an immigration amount higher and a low emigration amount. BBO algorithm needs the use of some terms where it's useful to precise the definition. In order to well understand this algorithm philosophy, a comparison is given to terminologies used by genetic algorithm and BBO algorithm where: Gene=*SIV*, Chromosome=Habitat=Island, Crossover=Migration. The species migrate between islandsstrategy is shewn by Fig.2.

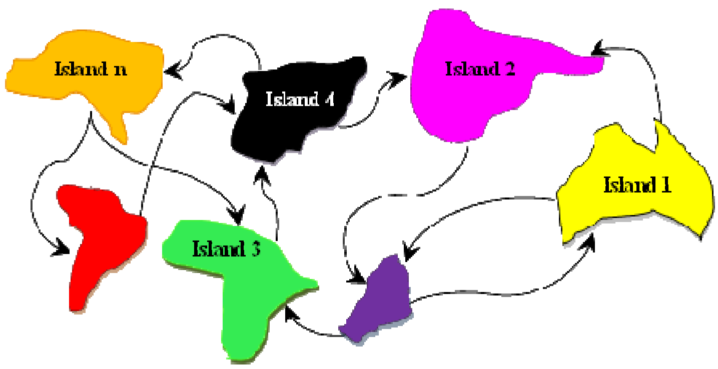

Fig. 2. Species migrate between islands

4. Graph theory and network reconfiguration

Modeling the distribution network reconfiguration is done as radial graph *G=(V,E)*, where the edges *E* signify switches device, *V* is the electrical buses vector (where load are connected to a substation buses). One graph, the radial reconfiguration of a distribution network is equivalent to a spanning tree, it is defined as a maximal sub-graph of G that connected without cycle [39]. Thus, the objectives is searching the optimum spanning tree in a graph satisfying all constraints.

5. Application of BBO to network reconfiguration

Generally distribution networks scheme contain many loops, but exploit is open loops (radial configuration). This means that from any bus in the graph it exists always one way into which we reach another bus. To determine an optimal configuration, BBO method is applied. The different parameters of this method are follows: *HSI*, presents the objective function (total active power loss) that corresponds to i^{th} combination, SIV_{iq}, presents the problem variables (switches stat open/close) of q^{th} loop for i^{th} habitat, the parameter H presents the solution for problem. Vector H can be defined as follows:

$H = [H_1 \ H_2 \ldots\ldots H_n]$, $n=1$…………….. up to population number.

The chromosome vector H_i with NL loop is given by following form:

$H_i = [SIV_{i1}\ SIV_{i2} \ldots\ldots SIV_{iNL}]$, $i=1$……..H……S, $q=1$……………….NL

H_i, can be written as follows: $H_i = [Sw_{1q}\ Sw_{2q} \ldots\ldots Sw_{NLq}]$

where, Sw_{iq} , present switches device the q^{th} loop for i^{th} branche.

The habitat vector (objective function) is given by following formulas:

$HSI_i = f(H_i)=[\ SIV_1\ SIV_2 \ldots\ldots SIV_n]$

The different points of the applied methods are cited as follows:

1: Choose the number of *SIV*, *NL*, and number of Habitat *H*, *S*. Initialize BBO parameters such as habitat Pmod modification probability, mutations probability, maximal mutations m_{max}, maximum immigration amount I, maximum emigration amount E, step size for the numeric integration. Maximal number of species is maximal and an elitism parameter.

2: Random choice of *SIV* initial value for each *H*.

3: In each habitat *H*, check radiality constraint of the network and insure that all buses are fed. If these conditions are satisfied, go to next **3**, if not, go to **6**.

4: Run apower flow analysis by backward/forward method and evaluate the equation 2.

5: Check equality and inequality constraints (4) and (6), if these constraints are not respected, penalize the objective function.

6: Determine the number of meshes isolated loads, and penalize the objective function (by equation 8).

7: According the *HSI* value, select the best chromosome.

8: Perform in a probabilistic manner a migration operation on each non elite habitat. Each set of solution will be then modified. Calculate anew the *HSI* value for the whole solutions.

9: Calculte the probability of space for each habitat and perform the mutation operation on the non elite *HSI* value of each habitat.

10: Go to **3** for a new generation, until stopping criteria is reached.

6. Simulations

In order to better study the performances of the methods used and the precision accuracy of the models, various distribution networks of different natures are proposed, three networks of study coming from the IEEE literature (33bus, 69bus and 84bus) and a real Algerian distribution network (116bus) are used. The IEEE networks are used for comparison with other studies in literature. The real network makes possible of both evaluation of our algorithm performance, and also to see to what point the algorithm can applied in practical matter. IEEE networks are generally known, but the Algerian network consist of 116 bus, 124 lines including 09 looping lines, and feeds a total load of 23886.36 kW and 17914.68 kVAr, this load is spread over 09 feeders. The nominal voltage of this network is 10 kV. The substation is connected to the medium voltage network via a 30/10 kV transformer. Fig.3, illustrate the Algerian 116bus distribution network topology. The lower and upper voltages limits considered in this work are 0.95pu and 1.05pu, respectively. Concerning the distributed generations, a generated power imposed of $P_{DG} = 0.3*(\sum P_{Di})$ with power factor of 0.8. This power is injected at the lowest bus voltage. This is to show the influence of DG unit on the reconfiguration distribution network and the various parameters of this network. Tab. 1 shows the size and DG location for each distribution network.

Tab. 1: Placement and Size of DG unit

	Distributed Generation		
	Bus location	Size	
		P (kW)	Q (kVAr)
33bus	18	1115	836
69bus	65	1141	856
84bus	10	1200	900
116bus	81	7166	5374

In simulation four cases are studied, case1, represents the first without reconfiguration and DG installation, case2, before DG installation, case3, only the DG installation and case4 after DG installation. In the different executions of the program (under MATLAB 2015a software), the optimal parameters of BBO algorithm used are, species count is 100, emigration rate E is 1, immigration rate I is 1, mutation probability is 0.005, and 100 iterations. Tab. 2, indicate the switches state, active power losses and minimum bus voltage of each distribution network for various cases considered. To attest the effectiveness of BBO algorithm, a comparison was made with other works of literature (see Tab. 3). Fig. 4, 5, 6 and 7 shows voltage profile for each cases. From these, we got that the improvement of voltages is due to optimization of the reconfiguration and the presence of DG unit. The same resonance with the total loss values can be shown. Case 4 (after DG installation) proved its effectiveness better than other cases by the minimization in addition to total losses with better voltage profile. Results got for the Algerian distribution network show that, the losses value in case3 is very well than case1, but after case4, the value of the demined losses decrease comparing to case1, which justify the significance of reconfiguring the network in attendance of DG.

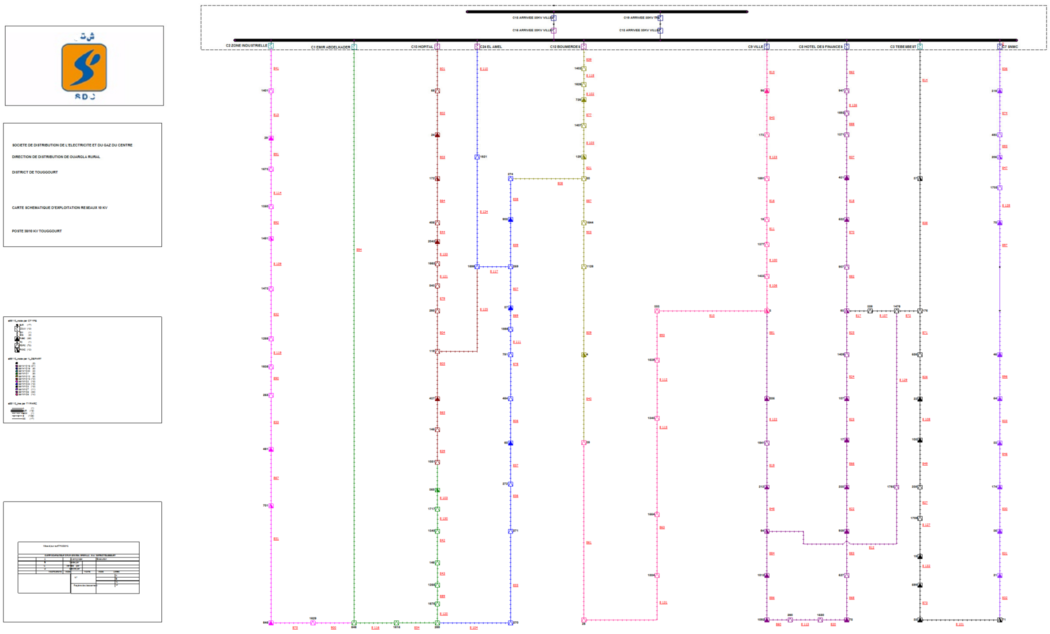

Fig. 3. Algerian 116 bus distribution network topology

Tab. 2: Result of BBO Algorithm

Distribution network	Before DG installation					After DG installation				
	RPL (kW)	MBV (pu)	SO	RPL (kW)	MBV (pu)	RPL (kW)	MBV (pu)	SO	RPL (kW)	MBV (pu)
33bus	202.50	0.9131	9-14-7 -32- 37	139.51	0.937	132.33	0.940	9-12-7 -34-37	53.712	0.976
69bus	224.78	0.9092	14-70-69- 56- 61	99.58	0.942	66.65	0.966	12-70-69 -57-21	42.10	0.973
84bus	531.81	0.9285	62-7-86-72- 13-89-90- 83- 92-39- 34- 42- 55	469.80	0.950	450.38	0.947	96-7-86-72- 13-89-90- 83- 92-39-34-42- 84	419.3	0.953
116bus	402.02	0.9696	99-75-79- 105-19-121- 68-60-107	367.65	0.975	684.90	0.974	103-75-79- 101-29-121- 27-70-25	242.71	0.986

RPL: Real power loss. – MBV: Minimum bus-voltage. – SO: Switches opened

Tab. 3: Vis other methods

Networks	Algorithm	Optimal reconfiguration (case 2)	Real power loss (kW)	Minimum bus-voltage (pu)
33bus	G.A [40]	33- 9- 34- 28- 36	140.60	0.9371
	H.B.M.O [19]	9- 14- 7- 32- 37	139.51	0.9378
	Proposed BBO	9- 14- 7- 32- 37	139.51	0.9378
69bus	F- G.A[41]	12- 55- 61- 69- 70	99.62	0.9427
	Proposed BBO	14- 70- 69- 58- 61	99.58	0.9427
84bus	A.I.S- A.C.O [42]	7- 13- 34- 39- 42- 55- 62- 72- 86- 89- 90- 91 -92	469.88	0.9479
	H.B.M.O [19]	7- 14- 34- 39- 42- 55- 62- 72- 83- 86- 88- 90- 92	482.14	0.9529
	Proposed BBO	42- 26- 34- 51- 122- 58- 39- 95- 97- 74- 71- 129- 130- 109- 23	469.80	0.9532

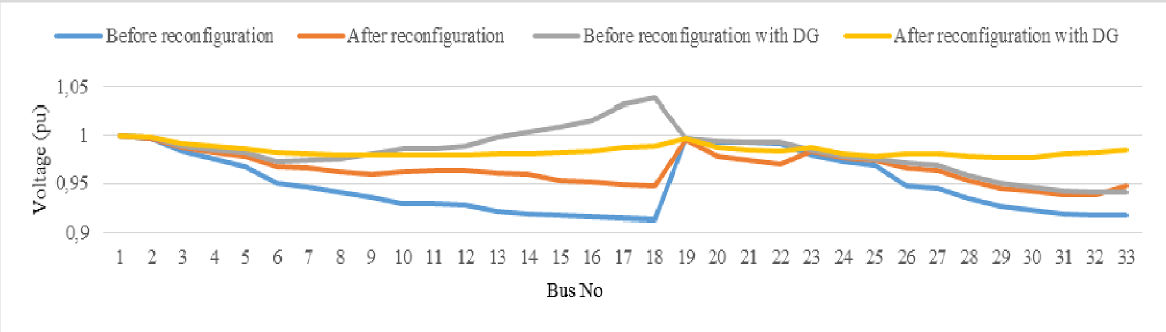

Fig. 4 . 33bus

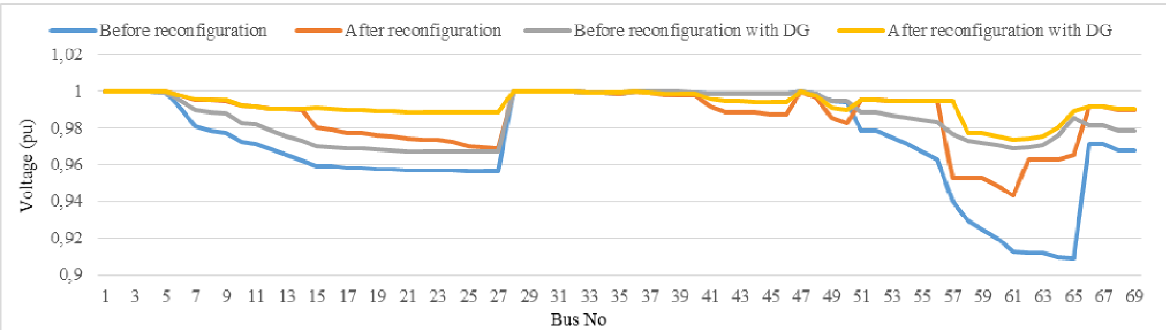

Fig. 5 . 69bus

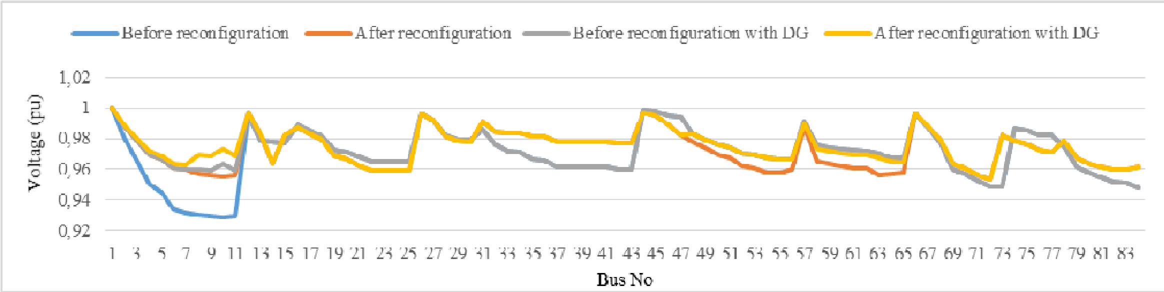

Fig.6 . 84bus

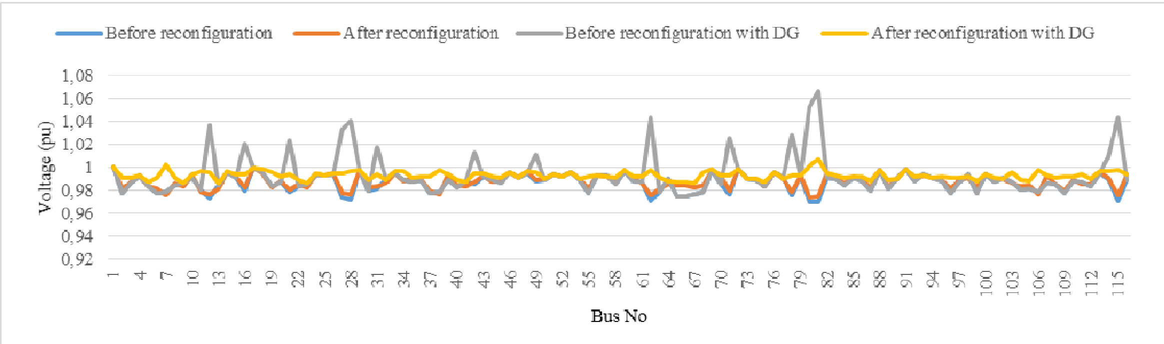

Fig. 7 . 116bus

5. Conclusion

A BBO algorithm is considered to optimize radial reconfiguration when managing distribution networks in the presence of distributed generation unit. The considered objective function is the minimization active power losses considering the constraints. The advantages of our approach is exposed in the quality of results compared to the others works. The method was tested on several IEEE networks (33bus, 69bus, 84bus) and attested on an Algerian distribution network (116bus).

References

[1] S. Civanlar, J. Grainger, H. Yin, S. S. Lee, "Distribution feeder reconfiguration for loss reduction" *IEEE Trans on Power Delivery,* Vol. 3, No. 3,pp. 1217-1223, 1988.

[2] D. Shirmohammadi, H. W. Hong, "Reconfiguration of electric distribution networks for resistive line loss reduction" *IEEE Trans on Power Delivery*, Vol. 4, No. 1, 1989.

[3] M. E. Baran, F. F. Wu, "Network reconfiguration in distribution systems for loss reduction and load balancing" *IEEE Trans ons on Power Delivery*, Vol. 4, No. 2, 1989.

[4] A.M.G. Solo, G. Ramakrishna, R.J. Sarfi, "A knowledge-based approach for network radiality in distribution system reconfiguration" *IEEE Trans on Power Engineering Society General Meeting*, 2006.

[5] K. Aoki, K. Nara, T. Satch, M. Kitagawa, K. Yamanaka, "New approximate optimization method for distribution system planning" *IEEE Trans on Power systems,* Vol. 5, No. 1, 1990.

[6] R. N. Abnndams, M. A. Laughton, "Optimal planning of networks using mixed-integer programming" *IEEProceeding,* Vol. 121, No. 2, pp. 139-148, 1974.

[7] M. Mosbah, S. Arif, R. D. Mohammedi, A. Hellal, "Optimum dynamic distribution network reconfiguration using minimum spanning tree algorithm" *Electrical Engineering Boumerdes (ICEE-B)*, *IEEEProceeding*, Boumerdes, Algeria, Octobre 29-31, 2017.

[8] R. A. Jabr, R. Singh, B. C. Pal, "Minimum loss network reconfiguration using mixed-integer convex programming" *IEEE Trans on Power Systems*, Vol. 27, No. 2, 2012.

[9] B.Tomoiaga *et al*, "Optimal reconfiguration of power distribution systems using a genetics" algorithm based on NSGA-II" *Energies*, Vol. 6, No. 3, pp. 1439–55,2013.

[10] S. Bahadoorsingh, *et al*,"Minimization of voltage sag costs by optimal reconfiguration of distributionnetwork using genetic algorithms" *IEEE Transon Power Delivery*, Vol . 22, No. 4, pp. 2271–2278, 2007.

[11] A.Abdelaziz, F.Mohamed, S.Mekhamer, M.Badr, "Distribution system reconfiguration using a modified tabu search algorithm" *Electr Power Syst Res*, Vol. 80, No. 8, pp. 943–53,2010.

[12] M. Caoyuan *et al* "Reconfiguration of distribution networks with distributed generation using a dual hybrid particle swarm optimization algorithm"*Mathematical Problems in Engineering (Hindawi)*, doi.org/10.1155/2017/1517435, 2017.

[13] G. I. Koong,*et al* "Gravitational search algorithm and selection approach for optimal distribution network configuration based on daily photovoltaic and loading variation" *Journal of Applied Mathematics (Hindawi)*, doi.org/10.1155/2015/894758, 2015.

[14] T. Niknam, "An efficient multi-objective HBMO algorithm for distribution feeder reconfiguration" *Exp Syst Appl,* Vol. 38, No. 3, pp. 2878-2887, 2011.

[15] L. Chang *et al*, "Control strategy for power loss reduction considering load variation with large penetration of distributed generation"*Advances in Electrical Engineering (Hindawi)*, doi.org/10.1155/2017/5764054, 2017.

[16] H. Salazar, R. Gallego, R. Romero, "Artificial neural networks and clustering techniques applied in the reconfiguration of distribution systems"*IEEE Transon Power Delivery* Vol. 21, No.3,1735–1742, 2006.

[17] O. A. Saleh, M. Elshahed, M. Elsayed, Enhancement of Radial Distribution Network with Distributed Generation and System Reconfiguration, J. Electrical Systems, 14(3), 36-50, 2018.

[18] T. Abdelmonem, H. A. Hassan, M. A. M. Farrag, Z. H. Osman1, A New Method for Loss Reduction in Distribution Networks via Network Reconfiguration" J. Electrical Systems, 14(3), 146-164, 2018.

[19] L. Hongwei *et al*, "An improved distribution network reconfiguration method based on minimum spanning tree algorithm and heuristic rules" *Electr Power Energy Syst*, Vol. 82, pp. 466–473, 2016.

[20] J.Z. Zhu, "Optimal reconfiguration of electrical distribution network using the refined genetic algorithm"*Electr Power Energy Syst,*Vol. 62, pp. 37–42,2002.

[21] Mustafa Mosbah, Salem Arif, Ridha D. Mohammedi and Rabie Zine, "Optimal Reconfiguration of an Algerian *Distribution Network in Presence of a Wind Turbine Using Genetic Algorithm", Book: Artificial Intelligence in Renewable Energetic Systems, Lecture Notes in Networks and Systems*, Vol. 35, 392-400, 2018.

[22] M. Mosbah, S. Arif, R. Zine, R. D. Mohammedi, S. H. Oudjana, "Optimal size and location of PV based DG-unit in transmission system using GA method for loss reduction" Journal of Electrical Engineering,Vol. 17(4), pp. 330-339, 2017.

[23] Ridha D. Mohammedi and Rabie Zine, Mustafa Mosbah, Salem Arif, "Optimum Network Reconfiguration using Grey Wolf Optimizer", TELKOMNIKA (Telecommunication Computing Electronics and Control), 16 (5), 2428-2435, 2018.

[24] G. Yang, J. Yang, "Automated classification of brain images using wavelet-energy and biogeography-based optimization" Multimedia Tools and Applications, Vol. 75, pp. 15601–15617, 2016.

[25] Simon. D,"Biogeography based optimization algorithm" IEEE Trans on Evolutionary Computation, Vol. 12, No. 6, pp. 702-713, 2008.

[26] N. Deo, "Graph theory with applications to engineering and computer science"*Prentice-Hall of India*, 2004.

[27] H. Ying-Yi, H. Saw-Yu, "Determination of network configuration considering multiobjective in distribution systems using genetic algorithms"*IEEE Trans on Power Syste,* Vol. 20, pp. 1062-1069, 2005.

[28] L. Liu, X. Y. Chen, "Reconfiguration of distribution networks based on fuzzy genetic algorithms"*CSEEProceeding,* Vol. 20, pp. 66-69, 2000.

[29] A. Ahuja, S. Das, A. Pahwa, "An AIS-ACO hybrid approach for multi-objective distribution system reconfiguration"*IEEE Trans on Power Syste,*Vol. 22, pp. 1101-1111, 2007.