A Model for Reconfiguration and Distributed Generation Allocation Considering Reduction of Network Losses

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A Model for Reconfiguration and Distributed Generation Allocation Considering Reduction of Network Losses

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This paper proposes a new model for reconfiguration and distributed generation allocation in distribution network conceding reduce network losses. The objective function involves minimizing losses using the new Ant Lion Optimizer (ALO) algorithm. The proposed reconfiguration on the unbalanced 33-bus IEEE base grid with and without Distributed Generation Sources (DGRs) as well as the use of capacitors have been investigated. In this study, a branching technique with an optimization method is used to determine the best network arrangement. Simulation studies are carried out under different scenarios. In each of the scenarios, the losses before and after the optimization are compared. The results indicate that, through using the proposed method the rate of the losses in the case study is reduced.

Keywords: Reconfiguration, Renewable Energy Sources (RESs), Power flow improvement, Adapted Ant Colony Algorithm

Introduction

In recent years, several studies have been conducted in the field of utilization of reconfiguration distribution networks. Reconfiguration of the distribution network with the goal of minimizing losses and improving the network voltage distribution profile using the improved Particle Algorithm (PA) has been studied by researcher[1-4]. Ant Lion Optimizer (ALO) has been introduced to solve the problem of reconfiguration the distribution network with the goal of reducing losses[5]. The proposed paper focuses on the following issues, i: Introduce a new method to DGs allocation considering reduce network losses in the smart distribution network, ii: Introduce fixable model for single and hybrid DGs allocation considering reduced network losses in the smart distribution system, iii: Solving reconfiguration problems in modern distribution networks. The structure of this paper is organized as follows: problem formulation is explained in Section 2. The system under study is presented in section 3. The result of simulation and discussion are shown in Section 4, and finally, conclusions are drawn in Section 5.

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Problem formulation

Ant Lion Optimizer (ALO) algorithm

ALO algorithm is defined as triple functions used for optimization problems as follow[1,2] (Eq. 1):

$ALO\ (A, B, C)$

$$\begin{cases} \emptyset \xrightarrow{A} \{M_{Ant}, M_{OA}, M_{Antlion}, M_{OAL}\} \\ \{M_{Ant}, M_{Antlion}\} \xrightarrow{B} \{M_{Ant}, M_{Antlion}\} \ \cdots \\ \{M_{Ant}, M_{Antlion}\} \xrightarrow{C} \{true, false\} \end{cases} \quad (1)$$

Where, A, Band C are functions that guarantee initial random responses, the initial population provided by the function A and criterion of the end, respectively. Also, $M_{Ant}, M_{Antlion}, M_{OA}$ and M_{OAL} are ants position matrix, the position of the ant lion, corresponding ants and corresponding of the ant's lion, respectively. In the ALO algorithm, ant and ant lion matrices are randomly initialized using function A. In each replication, function B updates the position of each ant against the selected Ant Lion by the Elitism and Roulette wheel operators. The position update border is initially defined in accordance with the current number of repetitions. Then, the update position is performed by two random steps around the selected ant lion and Elitism. When all the ants walk

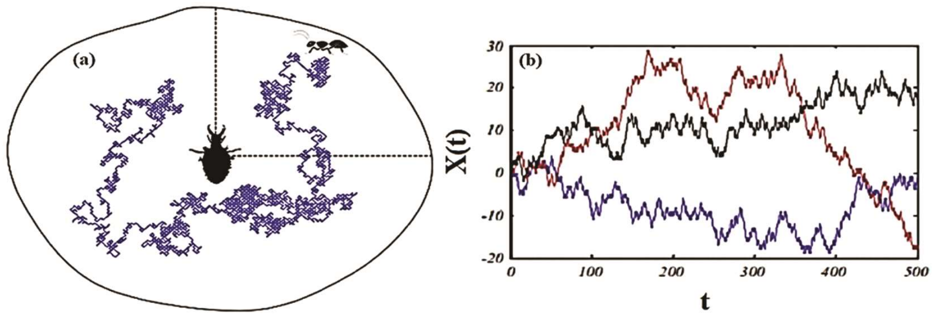

Fig. 1 — a) Random walks an ant nearby traps an Ant Lion, b) Three steps random carves[1,2]

randomly, they are evaluated by the compatibility function. If any of the ants are more compatible than any of the Ant Lion, their positions as new positions for the Ant Lion is considered as a next repetition. The best Ant Lionis compared (if necessary, replaced) to the best lion's ant which found during optimization (Elitism). These steps are repeated as long as the C function returns an incorrect value[1,2]. Figure 1 a and b show random walks an ant nearby traps an Ant Lion and three steps random carves of ants, respectively.

The proposed method

The paper proposes a new model for reconfiguration and DGs allocation in distribution network conceding reduce network losses. In other word, the optimal distribution network structure is designed to reduce losses using the ALO algorithm.

The objective is introduced as follows (Eq. 2):

$$Minimize, P_{Loss} = R_e\big(\sum_{m=1}^{l}\big(\sum_{j=a}^{c}\big(V_j(p) - Vj(k)I*(m) \qquad \ldots (2)$$

Where, l is the number of line, $V_j(p)$ is the voltage of bus p and phase j, $V_j(k)$ is the voltage of bus k and phase j, $I^*(m)$ is the current of line$m$ which flows between bus$p$ and bus$k$ and finally$j$ is the electrical network phases (a, b, c). The objective function should be calculated under the following constraints. The constraints of the problem are presented below:

- The balance of power in all buses :$P_i + jQ_i = V_{ai}I_{ai}^* + V_{bi}I_{bi}^* + V_{ci}I_{ci}^*, \quad i = 1,2,3,\ldots,n$
- Voltage limitation: $V^{min} \leq V_{pi} \leq V^{max}, p = a,b,c, i = 1,2,3,\ldots,n.$ (3)
- Lines current limitation: $I_{pi} \leq I_{pl}^{max}, p = a,b,c \quad l = 1,2,3,\ldots,l$

In addition, the structure of the network must be radial. In other word, another constraint is$n_b = n - 1$wheren_b is the total number of bus and n the total number of connection line. Moreover, no bus must be in island mode and its connecting to the network. This constraint is$\sum_{j=1}^{L}|A(i,j)| \geq 1, i = 1 - n.$ A is the divorced matrix of the network.

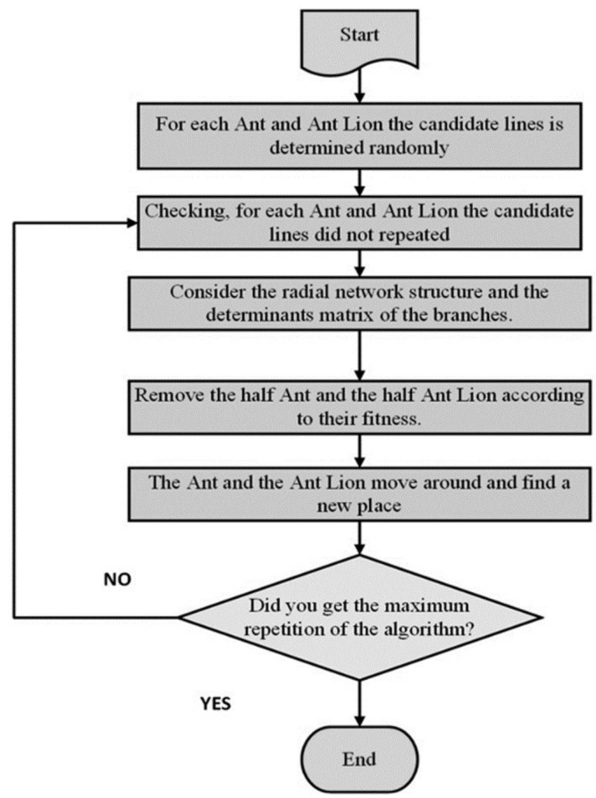

Fig. 2 — Proposed ALO algorithm

Implementing the algorithm

The proposed model needs to be solved by the power flow simulation. It is also necessary to extract the optimal structure while the network performance is analyzed. The ALO algorithm has been used to create a new structure and determine the optimal arrangement. This algorithm uses newly proposed indexes based on the optimization of the target function. Figure 2 shows the process of the proposed method. The distribution network is radial in normal conditions. However, the network has T-shaped lines that are open in normal conditions. These lines can be connected to the network by closing the power switches. In the Branch Exchange Technique (BET), when a transmission line is closed, another line closed in normal conditions is opened to maintain the radial structure of the network[3,4]. In this research, an optimal load distribution pattern is obtained with several branching operations. One line is closed in order to make a loop in the electrical network. The optimal power flow in the loop is obtained by applying KVL and KCL, where KVL is the sum of the residual voltage losses in the loop, which is equal to zero. This pattern is for power flow in a loop with minimum of losses[5]. To maintain the radial condition of the network, the line opens with the lowest current. This operation is performed to minimize network losses for all transmission lines.

Case Study

The case study (IEEE 33-bus) is shown in Figure 3. In order to study more broadly, several modifications have been made to the network, including adding DGs and compensating capacitors. The network data is shown in Appendix 1. The location and the size of DGs and capacitors in the 33-bus network are illustrated in Table 1.

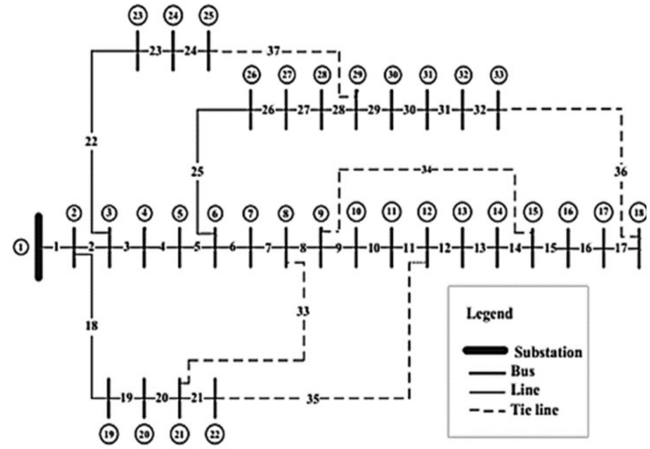

Fig. 3 — The unbalanced distribution network of 33-buses with DG presence and capacitor bank[3,4]

Table 1 — Location and size of DGs and capacitor in the 33-bus case study network

Bass	Capacity (kW, power factor)
12	100, 0.9 lag
13	215. 0.85 lag
15	100, 1
22	100, 0.9 lag
Bass	Capacity (kVAR)
5	45
9	60
12	15
14	30

Simulation Result and Discussion

The simulation studies are carried out under the following scenarios:

- First scenario: Basic network conditions without any DG or capacitors
- Second scenario: Network with 4 capacitor banks of 60kVAR, 15kVAR, 30kVAR and 45kVAR at buses 9, 12, 14 and 15[6].
- Third scenario: Adding a DG with a capacity of 215 kW/0.85 lag at the bus 13[6].
- Fourth scenario: A network with 3 DG 100 kW/ 0.9 lag, 100 kW/1, and 100 kW/0.9 lags installed on buses 12, 15, and 22[6].
- Fifth scenario: Network with a DG and four capacitors which are provided in the third scenario and second scenario, respectively.
- Sixth Scenario: Network with three DGs and four capacitors which are provided in the fourth scenario and second scenario, respectively.

After optimizing the target function in the simulation, the optimal conditions are obtained by changing the branches (reconfiguration) for the scenarios referred to the following table. The comparison of losses under different scenarios is presented in Table 2. It can be seen that, scenarios 6 and 4 have the lowest losses. In the sixth scenario, three DGs and four capacitors are used, and in the fourth scenario, three DGs are used. Therefore, the use of DG and capacitors simultaneously leads to a reduction in losses in the case study. Most of the losses are related to the first scenario, reconfirmation without DG and capacitor. The Adaptive Ant Colony Optimization (AACO) algorithm has been used for an unbalanced 33-bus network (no capacitor or DG) to reduce losses[7]. The reconfiguration scenario has been used to reduce costs without capacitor effect in some research[7]. Also, the combined GA method and fuzzy logic (FGA) method are used to solve the reconfiguration problems[8]. A comparison of the proposed ALO method with the AACO and FGA methods is presented in Table 3. Comparison of the results shows that, the proposed ALO method has the lowest losses (142.8512 kW) than other methods. Therefore, the performance of the proposed method is

Table 2 — Simulation results after optimizing the target function in the case study

First scenario		
Normal case	P_{loss} (kW)	207.45
	Candidate lines	33, 34, 35, 36, 37
With proposed model	P_{loss} (kW)/ min	142.85
	Candidate lines	7, 9, 14, 32, 37
Second scenario		
Normal case	P_{loss} (kW)	183.05
	Candidate lines	33, 34, 35, 36, 37
With proposed model	P_{loss} (kW)/ min	133.64
	Candidate lines	7, 9, 14, 28, 31
Third scenario		
Normal case	P_{loss} (kW)	186.99
	Candidate lines	33, 34, 35, 36, 37
With proposed model	P_{loss} (kW)/ min	136.97
	Candidate lines	7, 9, 14, 17, 28
Fourth scenario		
Normal case	P_{loss} (kW)	163.98
	Candidate lines	33, 34, 35, 36, 37
With proposed model	P_{loss} (kW)/ min	113.89
	Candidate lines	7, 9, 14, 28, 31
Fifth scenario		
Normal case	P_{loss} (kW)	151.3483
	Candidate lines	33, 34, 35, 36, 37
With proposed model	P_{loss} (kW)/ min	125.1013
	Candidate lines	7, 9, 14, 28, 32
Sixth Scenario		
Normal case	P_{loss} (kW)	136.7241
	Candidate lines	33, 34, 35, 36, 37
With proposed model	P_{loss} (kW)/ min	111.9738
	Candidate lines	6, 8, 9, 14, 27

Table 3 — Simulation results

The comparison of loss in different scenarios		
Objective Function	Candidate lines	P_{loss} (kW)/ min
First scenario	7, 9, 14, 32,37	142.85
Second scenario	7, 9, 14, 28, 31	133.64
Third scenario	7, 9, 14, 17, 28	136.97
Fourth scenario	7, 9, 14, 28, 31	113.89
Fifth scenario	7, 9, 14, 28, 32	125.1013
Sixth scenario	6, 8, 9, 14, 27	111.9738
Comparison the proposed ALO method with the AACO and FGA methods		
Algorithm	Candidate lines	P_{loss} (kW)/ min
Without reconfiguration	33,34,35,36,37	207.4453
AACO[7]	7,9,14,28,32	143.87
FGA[8]	7,9,14,28,36	148.69
ALO	7,9,14,32,37	142.8512
Comparison of losses in IEEE 33-bus balanced network after configuration		
Algorithm	Candidate lines	P_{loss} (kW)/ min
AACO[7]	7,9,14,32,37	139.55
EGA[9]	7,9,14,32,37	139.55
ACS[10]	7,9,14,28,32	139.98
HBMO[11]	7,9,14,32,37	139.55
ALO	7,9,14,32,37	139.55

better than other methods. Due to the better result obtained using the proposed method, power flow test (without capacitors and DGs) has been done in IEEE 33-bus balanced network and the results are also compared with the other methods. Table 3 shows the comparison between the proposed method and other methods to reduce losses in the 33-bus balanced network after configuration. According to Table 3, the amount of losses in IEEE 33-bus balanced network is 139.55 kW by the ALO method which is better than the CSA method. Also, this value is the same compared to the results of using other methods.

Conclusions

In this paper, the formulation and simulation results of the network reconfiguration with the use of capacitors and DGs in different scenarios with the aim of affecting losses in distribution networks were presented. In this study, the optimization algorithm was used to formulate the problem. First, the objective function of the problem was presented along with the constraints of the problem. Then the implementation of the ALO algorithm and Exchange Technique (BET) were described in detail. Simulation results were obtained under different scenarios of rearrangement with and without capacitors and DGs. Simulations for the unbalanced 33-bus IEEE standard network were carried out, and the simulation results were analyzed and compared under different scenarios and for different purposes. In the sixth scenario, three DGs and four capacitors are used, and in the fourth scenario, three DGs are used. Therefore, the use of DGs and capacitors simultaneously leads to a reduction in losses of the system. Most of the losses are related to the first scenario without using DGs and capacitors. Also, the configuration with the aim of reducing the losses for IEEE 33-bus balanced network was carried out using ALO and was compared with the results of previous studies (EGA[9], ACS[10], HBMO[11] and AACO[7]). The results indicate the effectiveness of the proposed method.

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Appendix

Line Number	Elementary Basses	End Basses	R1	X1	R2	X2	R3	X3
1	1	2	0/0922	0/0470	0/0922	0/0470	0/0922	0/0470
2	2	3	0/4930	0/2511	0/4930	0/2511	0/4930	0/2511
3	3	4	0/3660	0/1864	0/3660	0/1864	0/3660	0/1864
4	4	5	0/3811	0/1941	0/3811	0/1941	0/3811	0/1941
5	5	6	0/8190	0/7070	0/8190	0/7070	0/8190	0/7070
6	6	7	0/1872	0/6188	0/1872	0/6188	0/1872	0/6188
7	7	8	0/7114	0/2351	0/7114	0/2351	0/7114	0/2351
8	8	9	0/0300	0/7400	0/0300	0/7400	0/0300	0/7400
9	9	10	0/0440	0/7400	0/0440	0/7400	0/0440	0/7400
10	10	11	0/1966	0/0650	0/1966	0/0650	0/1966	0/0650
11	11	12	0/3744	0/1238	0/3744	0/1238	0/3744	0/1238
12	12	13	1/4680	1/1550	1/4680	1/1550	1/4680	1/1550
13	13	14	0/5416	0/7129	0/5416	0/7129	0/5416	0/7129
14	14	15	0/5910	0/5260	0/5910	0/5260	0/5910	0/5260
15	15	16	0/7463	0/5450	0/7463	0/5450	0/7463	0/5450
16	16	17	1/2890	1/7210	1/2890	1/7210	1/2890	1/7210
17	17	18	0/7320	0/5740	0/7320	0/5740	0/7320	0/5740
18	2	19	0/1640	0/1565	0/1640	0/1565	0/1640	0/1565
19	19	20	1/5042	1/3554	1/5042	1/3554	1/5042	1/3554
20	20	21	0/4095	0/4784	0/4095	0/4784	0/4095	0/4784
21	21	22	0/7089	0/9373	0/7089	0/9373	0/7089	0/9373
22	3	23	0/4512	0/3083	0/4512	0/3083	0/4512	0/3083
23	23	24	0/8980	0/7091	0/8980	0/7091	0/8980	0/7091
24	24	25	0/8960	0/7011	0/8960	0/7011	0/8960	0/7011
25	6	26	0/2030	0/1034	0/2030	0/1034	0/2030	0/1034
26	26	27	0/2842	0/1447	0/2842	0/1447	0/2842	0/1447
27	27	28	1/0590	0/9337	1/0590	0/9337	1/0590	0/9337
28	28	29	0/8042	0/7006	0/8042	0/7006	0/8042	0/7006
29	29	30	0/5075	0/2585	0/5075	0/2585	0/5075	0/2585
30	30	31	0/9744	0/9630	0/9744	0/9630	0/9744	0/9630
31	31	32	0/3105	0/3619	0/3105	0/3619	0/3105	0/3619
32	32	33	0/3410	0/5302	0/3410	0/5302	0/3410	0/5302
33	8	21	2/0000	2/0000	2/0000	2/0000	2/0000	2/0000
34	9	15	2/0000	2/0000	2/0000	2/0000	2/0000	2/0000
35	12	22	2/0000	2/0000	2/0000	2/0000	2/0000	2/0000
36	18	33	0/5000	0/5000	0/5000	0/5000	0/5000	0/5000
37	25	29	0/5000	0/5000	0/5000	0/5000	0/5000	0/5000