IJDACR
International Journal Of Digital Application & Contemporary Research

International Journal of Digital Application & Contemporary Research
Website: www.ijdacr.com (Volume 5, Issue 12, July 2017)

Reconfiguration and Capacitor Allocation in Distribution Systems to Reduce Power Losses and Improve Voltage Profiles using Ant lion Algorithm

Maryam Shokouhi[1] Shahrokh Shojaeian[2] Mehri Lotfi[1]

[1,2]Department of Engineering, Khomeinishahr Branch, Islamic Azad University, Isfahan, Iran
[2] Corresponding Author

Abstract— **Distribution networks are widest part of electrical grids. Due to low voltage and large expansion, the most of electric energy losses is related to these networks. Reconfiguration and capacitor placement are used in distribution networks, mainly to reduce power loss and improve voltage profile. In this paper, the optimal size and location of capacitors along with reconfiguration is investigated in IEEE 33-bus and 69-bus standard distribution systems. The purpose of optimization is power loss reduction and voltage profile improvement while satisfying radial network and power quality and practical constraints. Ant Lion optimizer (ALO) algorithm is used for this purpose. The obtained results show impact of these two methods and ALO algorithm in improving the system performance.**

Keywords— Ant Lion optimizer, voltage profile improvement, distribution system reconfiguration, power loss reduction, optimal capacitor placement.

I. INTRODUCTION

Electrical power distribution systems include radial circuits are interconnected through a number of normally closed switches. Existence of these switches makes it possible to feed buses through different possible routes. Because of the uncertainty of the system loads on different feeders varying from time to time, operation and control of distribution systems are complex, especially in areas where there is a high load density. Power loss in a distribution network in a fixed configuration for all variable loads, will be minimal. Thus, there is an occasional need to reconfigure the network [1]. Reconfiguration of the distribution network is really the change of the network topology, while maintaining the radial network structure. It is done in order to improve the system performance and it can be used to achieve that goal by appropriate change in the situation of the system switches. Thus, reconfiguration of the distribution network in order to reduce the power loss is: restructuring the distribution network so that at the first, network power loss is less, and secondly radial network structure is maintained.

In [1] a method is developed based on improved genetic algorithm to reconfigure the distribution network. The objective function provided in this paper has ignored necessary limits for line flow. In [2] distribution network reconfiguration is done using genetic algorithm. To code the reconfiguration, all closed switches had been placed in the strings of genetic algorithm. So strings were long and comparing them was a little difficult. In [3] the reconfiguration of the radial distribution network has been implemented by an innovative method and the genetic algorithm. In this paper, evaluation of any solution is dependent on the information obtained from all previous solutions. In [4] the network reconfiguration has been done using binary particle swarm algorithm. In large-scale networks the use of the binary method causes longer string and a little difficult operation.

As the nature of capacitor placement problem is complex combinatorial, different techniques have been followed by the authors in the past. The initial contribution was made by Schmill [5] using 2/3 rule for capacitor placement. Dynamic programming with assuming the capacitor sizes as discrete variables adapted by Duran [6]. The capacitor problem was viewed as a nonlinear problem by Grainger et al. [7], where variables were treated as continuous. The improvements in advanced optimization techniques such as genetic algorithm, micro genetic, particle swarm optimization, ant colony and differential evolution allowed the optimization procedures comparatively easier than the conventional procedures. Optimal capacitor placement was carried out through genetic algorithm by [8]. The number of locations was considered as the total variables for genetic algorithm. The micro-genetic concepts involving enhanced genetic algorithm was proposed in [9]. The power flow constraints were handled through fuzzy logic concepts. Optimization procedure through particle swarm optimization principle was adapted

IJDACR
International Journal Of Digital Application & Contemporary Research

International Journal of Digital Application & Contemporary Research
Website: www.ijdacr.com (Volume 5, Issue 12, July 2017)

in [10]. Optimization through plant growth simulation algorithm (PGSA) was first introduced for feeder reconfiguration in [5]. Later, the PGSA along with loss sensitivity factors was introduced [11] for optimal capacitor placement. Loss sensitivity factors were used to find the optimal location i.e. weak buses which require capacitor. PGSA was incorporated in order to find out the optimal sizing of the capacitors.

Some papers considered these two problems simultaneously. In [12], optimal capacitor placement and reconfiguration problem is considered as two consecutive stages and the branch exchange method is used for reconfiguration process. In [13], SA is used to solve optimal capacitor placement and reconfiguration. The amounts of capacitances are determined by a discrete optimization algorithm.

Simultaneous solution of these two problems has been approached with the objective of power loss minimization in [14] and the ACSA has been compared to SA and GA and its superior results have been presented. In [15], a modified PSO algorithm is used to solve the optimal capacitor placement and reconfiguration problems. The proposed objective function contains power loss minimization and cost reduction in specific periods of time. In [16], a heuristic algorithm is used for reliability evaluation considering protection schemes and isolation points in the distribution network. The problems are solved by Harmony Search Algorithm. In [17], a deterministic approach for network reconfiguration and a heuristic technique for optimal capacitor placement for power loss reduction and voltage profile improvement in distribution networks are presented. A minimum spanning tree (MST) algorithm is utilized to determine the configuration of minimum power losses along with a GA for optimal capacitor placement.

Since the classical methods are unable for solving scientific problems due to a number of constraints such as lack of derivative and non-linearity of the objective function, meta-heuristic algorithms have been used to solve this problem and enhance the abilities of speed and provide flexibility in solving issues. One of these algorithms is Ant Lion algorithm.

In this paper, the evaluation function used in the optimization algorithm is firstly introduced and detection methods of radial configurations are expressed. Then Ant Lion algorithm will be described. In addition, the studied networks are discussed. Considering the different scenarios, capacitor placement and reconfiguration of 33-bus and 69-bus IEEE standard systems will be made. MATLAB software / version 2010 is used for the study.

II. Problem Formulation

The main objective of this paper is to provide the right design for optimal placement of capacitors along with the distribution network reconfiguration, in such a way that the objective function is minimized and constraints are observed. So, for defining the problem, the main parts should be clearly defined and be appropriately modelled by precise mathematical equations. After defining the problem as mathematically, the intended problem can be solved by one of the optimization methods. In this study Ant Lion algorithm is used to optimally determine the size and location of capacitor and distribution network reconfiguration.

A. Objective Function

The objective function used in this paper consists of minimizing the active power loss and improving voltage profile shown in the following equation:

$$F = min(\alpha F_1 + \beta F_2) = \\ = \left[\alpha \sum_{i=1}^{N_b} P_{Loss}(i,j) + \beta \sum_{i=1}^{n} [V_i - V_{nom}] \right] \quad (1)$$

Here, $P_{LOSS}(i, j)$ represents the active power loss in tie-line between buses i and j. Also, n is the total number of buses in the system, N_b represents all lines on the network, V_i is bus voltage in pu, V_{nom} is reference nominal voltage, α and β are weighting coefficients

B. Problem Constraints

Adding a capacitor to the network should not bring the function of the network at risk. Also, the reconfiguration should be done in such a way that the radial structure of the network is maintained. This requires that all the requirements needed to achieve the best result in the problem are considered. Constraints considered in this paper include the following.

Load balance limit: for each bus the amount of the supplied power should be equal to the consumed power [19].

$$P_{Slack} = \sum_{i=1}^{n} P_{L_i} + P_{T,Loss} \quad (2)$$

where P_{slack} is the active power generated in a slack bus, P_{Li} is the active power demanded at bus i, $P_{T,Loss}$ is the active power loss of the whole network.

Bus voltage limit: the voltage of the buses should not exceed the authorized lower and upper limits [20].

$$|V_i|^{\min} \le |V_i| \le |V_i|^{\max} \quad (3)$$

IJDACR
International Journal Of Digital Application & Contemporary Research

International Journal of Digital Application & Contemporary Research
Website: www.ijdacr.com (Volume 5, Issue 12, July 2017)

Maximum output current limit of lines: power flow through lines must be such that maximum thermal capacity of grid lines is not violated.

$$\left|I_{ij}\right| \le \left|I_{ij}\right|^{\max} \tag{4}$$

Power loss limit after installing capacitor: power loss in the presence of a capacitor should be less than a scenario where there is not that capacitor in the network.

$$\sum Loss_i\left(with\,capacitor\right) \le \sum Loss_i\left(without\ capacitor\right) \tag{5}$$

Radial structure network:

$$\begin{aligned} &\det(A) = 1\ \ or\ -\left(radial\ system\right) \\ &\det\left(A\right) = 0\left(not\ radial\right) \end{aligned} \tag{6}$$

III. ALO Algorithm

Ant Lions (doodlebugs) belong to the Myrmeleontidae family and Neuroptera order (net-winged insects). The lifecycle of Ant Lions includes two main phases: larvae and adult. Their names originate from their unique hunting behavior and their favorite prey. An Ant lion larvae digs a cone-shaped pit in sand by moving along a circular path and throwing out sands with its massive jaw. Another interesting behaviour that has been observed in life style of Ant Lions is the relevancy of the size of the trap and two things: level of hunger and shape of the moon. Ant Lions tend to dig out larger traps as they become hungrier and/or when the moon is full [21].

A. Operators of the ALO algorithm

Ant Lions (doodlebugs) belong to the Myrmeleontidae family and Neuropteran order (net-winged insects). The lifecycle of Ant Lions includes two main phases: larvae and adult. Their names originate from their unique hunting behaviour and their favourite prey. An Ant lion larvae digs a cone-shaped pit in sand by moving along a circular path and throwing out sands with its massive jaw. Another interesting behaviour that has been observed in life style of Ant Lions is the relevancy of the size of the trap and two things: level of hunger and shape of the moon. Ant Lions tend to dig out larger traps as they become hungrier and/or when the moon is full [21].

B. Title and Author Details

The ALO algorithm mimics interaction between Ant Lions and ants in the trap. To model such interactions, ants are required to move over the search space, and Ant Lions are allowed to hunt them and become fitter using traps. Since ants move stochastically in nature when searching for food, a random walk is chosen for modelling ants' movement as follow:

$$\begin{aligned} x\left(t\right) = [0,\ &cumsum\left(2r\left(t_1\right)-1\right),\ cumsum\left(2r\left(t_2\right)-1\right), \\ &\ldots,\ cumsum\left(2r\left(t_n\right)-1\right)] \end{aligned} \tag{4}$$

r(t) is a stochastic function defined as follows:

$$r\left(t\right) = \begin{cases} 1 & if\ \ rand > 0.5 \\ 0 & if\ \ rand \le 0.5 \end{cases} \tag{5}$$

C. Random walks of ants

In order to keep the random walks inside the search space, they are normalized using the following equation (min–max normalization):

$$X_i^t = \frac{\left(X_i^t - a_i\right)\times\left(d_i - c_i^t\right)}{d_i^t - a_i} + c_i \tag{6}$$

D. Sliding ants towards Ant lion

With the mechanisms proposed so far, Ant Lions are able to build traps proportional to their fitness and ants are required to move randomly. However, Ant Lions shoot sands outwards the center of the pit once they realize that an ant is in the trap. This behavior slides down the trapped ant that is trying to escape. For mathematically modeling this behavior, the radius of ants' random walks hyper-sphere is decreased adaptively. The following equations are proposed in this regard:

$$c^t = \frac{c^t}{I} \tag{7}$$

$$d^t = \frac{d^t}{I} \tag{8}$$

E. Catching prey and re-building the pit

The final stage of hunt is when an ant reaches the bottom of the pit and is caught in the Ant lion's jaw. After this stage, the Ant lion pulls the ant inside the sand and consumes its body. For mimicking this process, it is assumed that catching prey occur when ants becomes fitter (goes inside sand) than its corresponding Ant lion. An Ant Lions then required to update its position to the latest position of the hunted ant to enhance its chance of catching new prey. The following equation is proposed in this regard:

$$Antlion_j^t = Ant_i^t \quad if \quad f\left(Ant_i^t\right) > f\left(Antlion_j^t\right) \tag{9}$$

F. Elitism

In this study the best Ant lion obtained so far in each iteration is saved and considered as an elite. Therefore, it is assumed that every ant randomly walks around a selected Ant lion by the roulette wheel and the elite simultaneously as follows:

IJDACR
International Journal Of Digital Application & Contemporary Research

International Journal of Digital Application & Contemporary Research
Website: www.ijdacr.com (Volume 5, Issue 12, July 2017)

$$Ant_i^t = \frac{R_A^t + R_E^t}{2} \tag{15}$$

G. ALO algorithm

The pseudo codes of the ALO algorithm are defined as follows [21]:

Initialize the first population of ants and Ant Lions randomly
Calculate the fitness of ants and Ant Lions
Find the best Ant Lions and assume it as the elite (determined optimum)
while the end criterion is not satisfied
    for every ant
        Select an Ant lion using Roulette wheel
        Update c and d using equations Eqs. (10) and (11)
        Create a random walk and normalize it using Eqs. (7) and (9)
        Update the position of ant using (13)
    end for
    Calculate the fitness of all ants
    Replace an Ant lion with its corresponding ant it if becomes fitter (Eq. (12))
    Update elite if an Ant lion becomes fitter than the elite
end while
Return elite

IV. RESULTS AND DISCUSSIONS

In this section, results are provided for IEEE 33-bus and 69-bus standard distribution systems, respectively. Three states are studied in these systems as below:

Scenario I: only capacitor placement
Scenario II: only reconfiguration
Scenario III: capacitor placement and reconfiguration

A. IEEE 33-bus test system

This is a medium scale, 12.66kV, radial distribution system with 33 buses. The line, load and tie line data of this test system are taken from [22]. It consists of five tie lines and 32 sectionalize switches. The normally open tie switches are 33–37, and the normally closed sectionalize switches are 1–32. The single line diagram of 33-bus system is shown in Fig. 1. The dotted lines represent the tie lines. The total real and reactive power loads of the system are 3.72MW and 2.3MVAR, respectively. The total active power loss for the base case calculated from power flow is 211.0983kW. The minimum and maximum voltage magnitudes of the system are 0.9038pu and 1.0pu occurring at buses no. 18 and 1, respectively.

The results obtained from the optimization for senario I i.e. only capacitor placement is provided in Table I. It is seen that the best buses to be installed capacitors are 10, 24 and 30. This action causes to reduce active power loss equal to 34%. Also, minimum voltage is enhanced to 0.9332pu.

TABLE I
RESULTS FOR ONLY CAPACITOR PLACEMENT IN IEEE 33-BUS DISTRIBUTION SYSTEM

Items	**Values**
Location (bus)	10 24 30
Size	456.7761,956.5372,577.3771
P_{Loss} (kW)	139.0112
Max Voltage (pu)	1.0000
Min Voltage (pu)	0.9332

The results obtained from the optimization for senario II i.e. only reconfiguration is provided in Table II. It is seen that line outs are 1, 7, 9, 14 and 32. Tie lines are also busses 33 to 37. This action causes to reduce active power loss equal to 31%. Also, minimum voltage is enhanced to 0.9355pu.
The results obtained from the optimization for senario III i.e. capacitor placement and reconfiguration is provided in Table III. It is seen that the best busses to be installed capacitors are busses 4, 24 and 30. Also, line outs are 2, 3, 9, 16 and 18, and tie lines are 4, 24 and 30. This action causes to reduce active power loss equal to 49%. Also, minimum voltage is enhanced to 0.9484pu.
Also, the bus voltage profile provided for 33-bus system in Fig. 2 show that it is improved by capacitor placement or reconfiguration. This improvement is higher for simultaneously doing both of them.

TABLE II
RESULTS FOR ONLY RECONFIGURATION IN IEEE 33-BUS DISTRIBUTION SYSTEM

Items	1,7,9,14,32
Line out	33,34,35,36,37
Tie line	145.0452
P_{Loss} (kW)	1.0000
Max Voltage (pu)	0.9355
Min Voltage (pu)	1,7,9,14,32

TABLE III
RESULTS FOR CAPACITOR PLACEMENT AND RECONFIGURATION IN IEEE 33-BUS DISTRIBUTION SYSTEM

Items	**Values**
Line out	2 3 9 16 18
Tie line	33 34 36 37
Cap Location (bus)	4 24 30
Cap Size (kVAR)	468.2426,997.6376,409.6488
P_{Loss} (kW)	107.5622
Max Voltage (pu)	1.0000
Min Voltage (pu)	0.9484

IJDACR
ISSN: 2319-4863

IJDACR
International Journal Of Digital Application & Contemporary Research

International Journal of Digital Application & Contemporary Research
Website: www.ijdacr.com (Volume 5, Issue 12, July 2017)

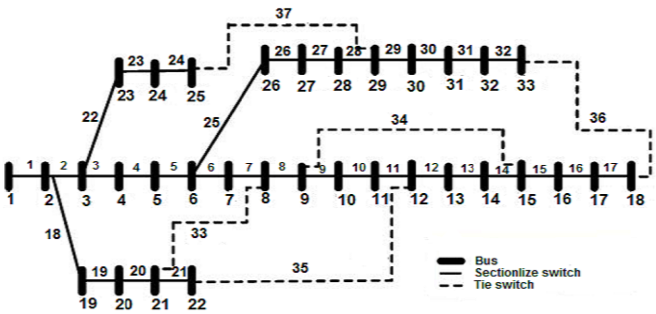

Fig. 1: IEEE 33-bus Distribution System

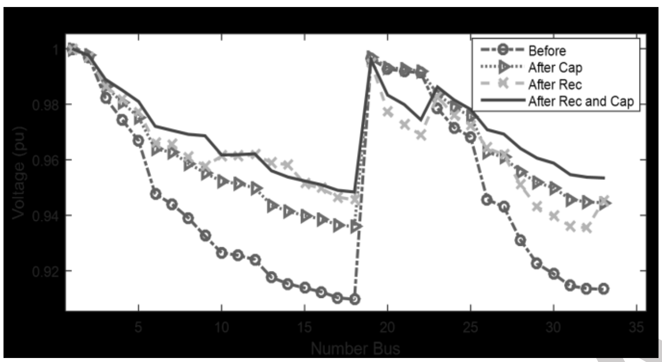

Fig. 2: Bus voltage profile for IEEE 33-bus distribution system

B. IEEE 69-bus test system

This is a medium scale, 12.66kV, radial distribution system with 69 buses. The line, load and tie line data of this test system are taken from [22]. It consists of five tie lines and 69 sectionalize switches. The normally open tie switches are 69–73, and the normally closed sectionalize switches are 1–68. The single line diagram of 69-bus system is shown in Fig. 3. The dotted lines represent the tie lines. The total real and reactive power loads of the system are 3.802 MW and 2.6946MVAR, respectively. The total active power loss for the base case calculated from power flow is 225kW. The minimum and maximum voltage magnitudes of the system are 0.9092pu and 1pu occurring at buses no. 54 and 1, respectively.

The results obtained from the optimization for senario I i.e. only capacitor placement is provided in Table IV. It is seen that the best buses to be installed capacitors are 61, 63 and 66. This action causes to reduce active power loss equal to 36%. Also, minimum voltage is enhanced to 0.9320pu.

The results obtained from the optimization for senario II i.e. only reconfiguration is provided in Table V. It is seen that line outs are 12, 17, 33, 45 and 50. Tie lines are also busses 71 to 73. This action causes to reduce active power loss equal to 56%. Also, minimum voltage is enhanced to 0.9428pu.

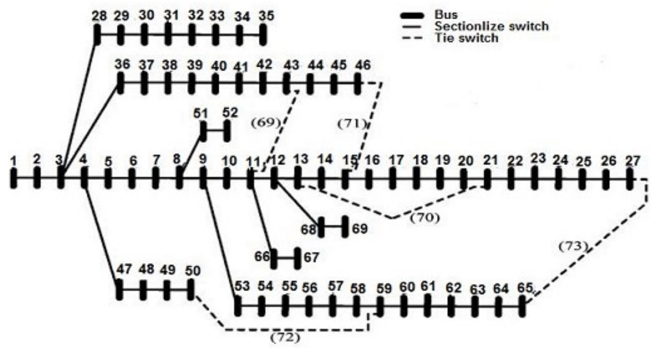

Fig. 3: IEEE 69-bus Distribution System

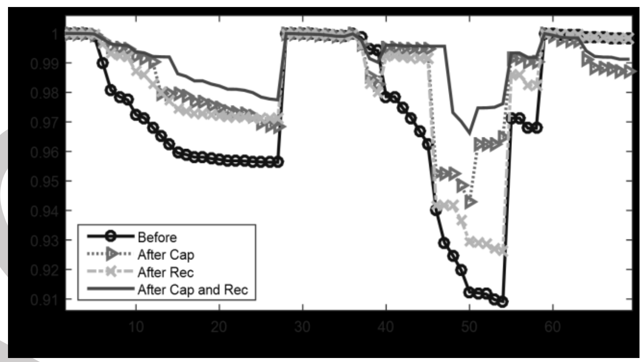

Fig. 4: Bus voltage profile for IEEE 69-bus distribution system

TABLE IV
RESULTS FOR ONLY CAPACITOR PLACEMENT IN IEEE 69-BUS DISTRIBUTION SYSTEM

Items	Values
Location (bus)	61 63 66
Size	647.6268,534.757,839.1097
P_{Loss} (kW)	144.5725
Max Voltage (pu)	1.0000
Min Voltage (pu)	0.9320

TABLE V
RESULTS FOR ONLY RECONFIGURATION IN IEEE 69-BUS DISTRIBUTION SYSTEM

Items	Values
Line out	12,17,33,45,50
Tie line	71,72,73
P_{Loss} (kW)	99.8179
Max Voltage (pu)	1.0000
Min Voltage (pu)	0.9428

The results obtained from the optimization for senario III i.e. capacitor placement and reconfiguration is provided in Table 6. It is seen that the best busses to be installed capacitors are busses 11, 50 and 53. Also, line outs are 6, 14, 19, 47 and 50, and tie lines are 72-74. This action causes to reduce

IJDACR
International Journal Of Digital Application & Contemporary Research

International Journal of Digital Application & Contemporary Research
Website: www.ijdacr.com (Volume 5, Issue 12, July 2017)

active power loss equal to 71%. Also, minimum voltage is enhanced to 0.9663pu.

TABLE VI
RESULTS FOR CAPACITOR PLACEMENT AND RECONFIGURATION IN IEEE 69-BUS DISTRIBUTION SYSTEM

Items	Values
Line out	6,14,19,47,50
Tie line	72,73,74
Cap Location (bus)	11,50,53
Cap Size (kVAR)	383.611,342.9262,999.9996
P_{Loss} (kW)	65.6969
Max Voltage (pu)	1.0000
Min Voltage (pu)	0.9663

Also, the bus voltage profile provided for 69-bus system in Fig. 4 show that it is improved by capacitor placement or reconfiguration. This improvement is higher for simultaneously doing both of them.

In an initial investigation it is specified that the capacitor installation and reconfiguration cause to reduce power loss and increase voltage stability. Also, according to the results it can be deduced in order that the installation of capacitors has the greatest effect on the network, a reconfiguration along with the installation of these devices is necessary.

V. CONCLUSION

This paper presents a useful method for distribution network reconfiguration along with fixed capacitors. For this purpose, the objective function is introduced to improve the voltage profile and reduce power loss, leading to optimal location and size of capacitors as well as the best possible configuration for the network.

In this paper, the Ant Lion algorithm is used to solve the optimization problem in different scenarios. This algorithm is tested on the IEEE 33s and 69-bus distribution systems. The results indicated that the correct installation of capacitors in parallel with the reconfiguration improves voltage profile and reduces power loss. Also, it was observed that Ant Lion algorithm for optimization problem leads to good results.

REFERENCES

[1] Zhu, J.Z. 2002 Optimal reconfiguration of electrical distribution network using the refined genetic algorithm, Electric Power Systems Research

[2] Torres, J.L, Guardado, L. Maximov, and Melgoza E. 2014, A genetic algorithm based on the edge window decoder technique to optimize power distribution systems reconfiguration, Electrical Power and Energy Systems

[3] Braz, H.D., Souza, B.A.., 2011 Distribution Network Reconfiguration Using Genetic Algorithms With Sequential Encoding: Subtractive and Additive Approaches, IEEE Transactions on Power Systems

[4] Amanulla, M., Chakrabarti, S, 2012 Reconfiguration of Power Distribution Systems Considering Reliability and Power Loss, IEEE Transactions on Power Delivery

[5] Schmill JV. 1965 Optimum size and location of shunt capacitors on distribution feeders, IEEE Trans Power Apparatus and System

[6] Duran H. 1968 Optimum number, location and size of shunt capacitors in radial distribution feeders: a dynamic programming approach, IEEE Transactions on Power Apparatus and System

[7] Grainger J. J., Lee S. H., 1981 Optimum size and location of shunt capacitors for reduction of losses on distribution feeders", IEEE Transactions on Power Apparatus and System

[8] Das D., 2002 Reactive power compensation for radial distribution networks using genetic algorithms, Electrical Power Energy Systems

[9] Souza B. A., Alves H. N., and Ferreira H. A., 2004 Microgenetic algorithms and fuzzy logic applied to the optimal placement of capacitor banks in distribution networks, IEEE Transactions on Power Systems

[10] Prakash, K., Sydulu M., 2007 Particle swarm optimization based capacitor placement on radial distribution systems, In Proceedings of the IEEE power engineering society general meeting

[11] Srinivasas, Rao R., Narasimham, S. V. L., Ramalingaraju, M., 2011 Optimal capacitor placement in a radial distribution system using Plant Growth Simulation Algorithm, Electrical Power Energy and Systems

[12] Peponis, G.J., Papadopulos, M.P., Hatziargyriou, N.D. 1996 Optimal operation of distribution networks, IEEE Transactions on Power Systems

[13] Dan, J., Baldick, R., 1996 Optimal electric distribution system switch reconfiguration and capacitor control. IEEE Transactions on Power Systems

[14] Chang, C.F., 2008 Reconfiguration and capacitor placement for loss reduction of distribution systems by ant colony search algorithm, IEEE Transactions on Power Systems

[15] Pooya, R., Mehdi, V. 2010 Distribution system efficiency improvement by reconfiguration and capacitor placement using a modified particle swarm optimization algorithm, In Proceedings of the IEEE Electrical Power and Energy Conference

[16] Pooya, R., Mehdi, V., Hajipour, E., 2011 Reconfiguration and capacitor placement in radial distribution systems for loss reduction and reliability enhancement, In Proceedings of the Intelligent system application to power systems

[17] Montoya, D.P., Ramirez, J.M. 2012 Reconfiguration and optimal capacitor placement for losses reduction, In Proceedings of the IEEE/PES transmission and distribution Latin America Conference and Exposition

[18] Ehsan, M., Javad, R., 2009 A new method for load flow on radial distribution network, In Proceedings of the 12th Iranian Student Conference on electrical engineering

[19] Ahuja, A, Das, S., 2007 An AIS-ACO Hybrid Approach for Multi-Objective Distribution System Reconfiguration, IEEE Transactions on Power Systems

[20] Cheng H.C., Kou C.C., 2010 Network reconfiguration in distribution system using simulated annealing, Electric Power System

[21] Mirjalili S. 2015 The Ant Lion optimizer, Advance Engineering Software

[22] Baran, M.E., F.F., Wu, 1989 Network reconfiguration in distribution systems for loss reduction and load balancing, IEEE Transactions on Power