Bulletin of Environment, Pharmacology and Life Sciences
Bull. Env. Pharmacol. Life Sci., Vol 3 [9] August 2014: 28-36

Online ISSN 2277-1808
Journal's URL:http://www.bepls.com
CODEN: BEPLAD
Global Impact Factor 0.533
Universal Impact Factor 0.9804

ORIGINAL ARTICLE

Combination of Optimal Conductor Selection and Capacitor Placement in Radial Distribution Systems Using BFA Method

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ABSTRACT
In This paper presents an approach for optimal placement and sizing of fixed capacitor banks and also optimal conductor selection in radial distribution networks for the purpose of economic minimization of loss and enhancement of voltage. The objective function includes the cost of power losses, voltage profile, fixed capacitor banks and also type of conductor selection. Constraints include voltage limit, maximum permissible carrying current of conductors, size of available capacitors and type of conductors. The optimization problem is solved by the Imperialism Competitive algorithm method and the size and site capacitor banks and type of conductors is determined. To demonstrate the validity of the proposed algorithm, computer simulations are carried out on actual power network of Kerman city, Iran and the simulation results are presented and discussed
Keywords: BFA Algorithm, Radial Distribution Systems, Loss Reduction, Capacitor placement, Conductor Selection.

Received 03.06.2014 **Revised 12.07.2014** **Accepted 22.07.2014**

INTRODUCTION

The main objective of an electrical distribution system (EDS) is providing a reliable and cost-effective service to consumers with considering power quality within standard ranges. Thus, it is necessary to properly plan the EDS and thus evaluate several aspects such as, new equipment installation cost, equipment utilization rate, and quality of service, reliability of the distribution system and loss minimization, considering an increase of system loads, and newly installed loads for the planning horizon [1]. The loss minimization in distribution systems has assumed greater significance recently since the trend towards distribution automation will require the most efficient operating scenario for economic viability variations. The power losses in distribution systems correspond to about 78% of total losses in electric power systems [2].The advantages with the addition of shunt capacitors banks are to improve the power factor, feeder voltage profile, Power loss reduction and increases available capacity of feeders.

Therefore it is important to find optimal location and sizes of capacitors in the system to achieve the above mentioned objectives. Since, the optimal capacitor placement is a complicated combinatorial optimization problem, many different optimization techniques and algorithms have been proposed in the past. H. Ng et al, [3] proposed the capacitor placement problem by using fuzzy approximate reasoning. Ji Pyng Chiou et al, [4] proposed the variable scale hybrid differential evolution algorithm for the capacitor placement in distribution system. However, considered only the losses in the lines and the quantification were defined for the line losses only.

There are several parameters to be taken into account to model the conductor size selection (CSS) problems such as: conductor's economic life, discount rate, cable and installation costs and type of circuit (overhead or underground). Dynamic programming approach was utilized to solve the CSS problem in [5]. They presents models to represent feeder cost, energy loss and voltage regulation as a function of a conductor cross-section. In the conductor size selection performed with consideration of financial and engineering criteria in the feeder. In the CSS problem is solving using heuristic methods. Reference uses a selection phase by means of economic criteria, followed by a technical selection using a sensitivity index that seeks to ensure a feasible operation of the EDS, whereas presents a heuristic method using a novel sensitivity index for the reactive power injections. The heuristic methods are robust, easily applied; however, they normally converge to a local optimum solution. In, a mixed integer linear model for the problem of conductor selection size in radial distribution systems is presented [6].

In this paper, a combination of both capacitor placement and conductor selection methods is developed to reduce the loss of a distribution network. In this method the objective function of capacitor placement and conductor selection is to reduce the power loss within minimum costs and enhancing the voltage profile. The constraints are voltage limits, allowable current energy capacity of selected conductors. To solve this optimization problem, BFA method is used. To demonstrate the validity of the proposed algorithm, computer simulations are carried out on actual power network of Kerman Province, Iran and the simulation results are presented and discussed. The results show that proposed objective function minimizes the loss of the system by considering all of the constraints and incorporating capacitors and conductor's selection.

PROBLEM FORMULATIONS

Power Flow Analysis Method

Power flow evaluation includes the calculation of bus voltages and line flows of a network. A single-phase representation is adequate because power systems are usually balanced. Associated with each bus, there are four quantities to be determined or specified: the real and reactive powers, the voltage magnitude and phase angle. Figure 1 shows an m-bus radial distribution system wherein bus i has a load and a shunt capacitor [6].

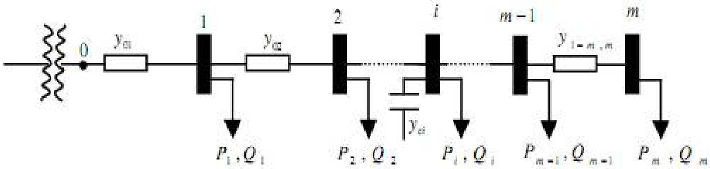

Fig. 1: Single line diagram of a radial distribution feeder

Notation:

$Y_{i,i+1}=1/(R_{i,i+1}+j\,X_{i,i+1})$;Admittance of the line section between buses i and i+1,$R_{i,i+1}$, $X_{i,i+1}$; Resistance and reactance of the line connecting buses i and i+1,P_i , Q_i; Load active and reactive powers at bus i. At bus i, we have

$$P_i \ -Q_i \ =V_i^* I_i \qquad (1)$$

Where I_i is positive when it flows into the system and m is the number of buses in the feeder. The bus voltages and line losses can be solved by the Gauss-Seidel iterative method employing the following formula [7]:

$$V_i^{(k+1)}=\frac{1}{Y_{ij}}\left(\frac{P_i \ -jQ_i}{V_i^{*(k)}}-\sum_{\substack{n=1\\ n\neq m}}^{m} Y_{in} V_n\right) \quad i=1,\ldots,m \quad (2)$$

At the power frequency, the power loss in the line section between buses i and i+1 may then be computed by:

$$P_{(i,i+1)}=R_{i,i+1}\cdot\left[\left|V_{i+1}-V_i\right|\cdot\left|Y_{i,i+1}\right|\right]^2 \qquad (3)$$

The purpose of placing compensating capacitors and optimal conductors is to obtain the lower the total power loss and bring the bus voltages within their specified while minimizing the total cost. The total power loss is given by Eq. (4);[7].

$$P_i = \sum_{i=0}^{m-1} P_{(i,i+1)} \qquad (4)$$

The Backward Sweep calculates the current injected into each branch as a function of the end node voltages. It performs a current summation while updating voltages. Bus voltages at the end nodes are initialized for the first iteration. Starting at the end buses, each branch is traversed toward the source bus updating the voltage and calculating the current injected into each bus. These calculated currents are stored and used in the subsequent Forward Sweep calculations. The calculated source voltage is used for mismatch calculation as the termination criteria by comparing it to the specified source voltage. The Forward Sweep calculates node voltages as a function of the currents injected into each bus. The Forward Sweep is a voltage drop calculation with the constraint that the source voltage used is the specified nominal voltage at the beginning of each forward sweep. The voltage is calculated at each bus, beginning at the source bus and traversing out to the end buses using the currents calculated in previous the Backward Sweep [5].Flowchart of the Backward-Forward sweep method is depicted in Figure 2.

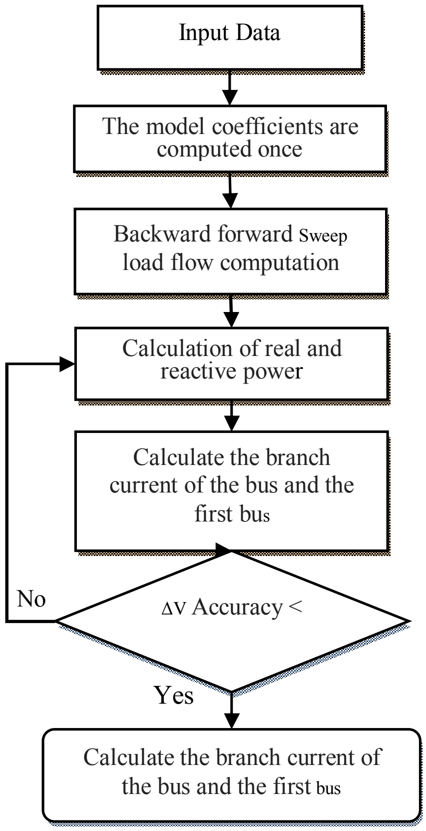

Figure 2: Flowchart of the Backward-Forward sweep method

Formulation

Capacitor Placement

Considering the practical capacitors, there exists a finite number of standard sizes which are integer multiples of the smallest size Q_0^c. Besides, the cost per Kvar varies from one size to another. In general, capacitors of larger size have lower unit prices. The available capacitor size is usually limited to

$$Q_c^{max} = LQ_c \qquad (5)$$

Where L is an integer. Therefore, for each installation location, there are L capacitor sizes [$1Q_c$, $2Q_c$, $3Q_c$, …, LQc] available. Given the annual installation cost for each compensated bus, the total cost due to capacitor placement and power loss change is written as

$$F1 = K_p \times P_T^{LOSS} + \sum_{i}^{c} \left(K_{cf} + K_i^c Q_i^c\right) \qquad (6)$$

Where n is number of candidate locations for capacitor placement, Kp is the equivalent annual cost per unit of power loss in $/(Kw-year); K_{cf} is the fixed cost for the capacitor placement. Constant K_i^c is the annual capacitor installation cost, and, i = 1, 2, ..., n are the indices of the buses selected for compensation. The bus reactive compensation power is limited to

$$Q_i^c \leq \sum_{i=1}^{n} Q_{Li} \qquad (7)$$

Where $1Q_c$ and LQ_c are the reactive power compensated at bus i and the reactive load power at bus i, respectively.

Conductor Type Selection

Considering the objective is selection of conductor's size from the available size in each branch of the system which minimizes the sum of depreciation on capital investment and cost of energy losses while maintaining the voltages at different buses within the limits. In this case, the objective function with conductor *c* in branch *i is* written as

$$F2 = CE(i, c) + \gamma * A(c) * \{C(c) + L(i)\} \qquad (8)$$

Where CE (i,c) is the Cost of Energy Losses, n is buss number, i is the branch number and w is the weighting factor[13]. The annual cost of loss in branch *i* with conductor type *k* is,

$$CE(i,c) = P\,L(i, c) * \{KP + KE * L_{SF} * T\} \qquad (9)$$

Where K_p is annual demand cost due to Power Loss ($/kW), K_E is annual cost due to Energy Loss ($/kWh), δ is Loss factor, ($PL_{(i,c)}$) is real Power Loss of branch *i* under peak load conditions with conductor type *c* and *T* is the time period in hours (8760 hours). Where L_{SF} is Interest and depreciation factor, C_c is cost of type conductor ($/km), A(c) is cross-sectional area of *c* type conductor and L(i) is length of branch i (km).

Objective Function

In each optimization problem, objective function should be defined. Eq. (11) illustrates the proposed objective function in this paper. This objective function aims at minimizing the total annual cost due to capacitor placement, conductor selection and power losses with constraints that include limits on voltage Eq. (13), maximum permissible carrying current of conductors Eq. (14), size of installed capacitors and type of selected conductors. These constraints are added as penalty functions to the objective function.

$$F = F1 + F2 \qquad (11)$$

$$V_{min} \leq |V_i| \leq V_{max} \qquad (12)$$

$$I_{(l)} \leq I_{max(l)} \qquad (13)$$

Where:

V_{min}, V_{max}: minimum and maximum permissible bus voltage. I_{max}^{l}: Maximum permissible carrying current of installed conductors in L^{th} section.The flow chart of proposed method is depicted in Figure 3.

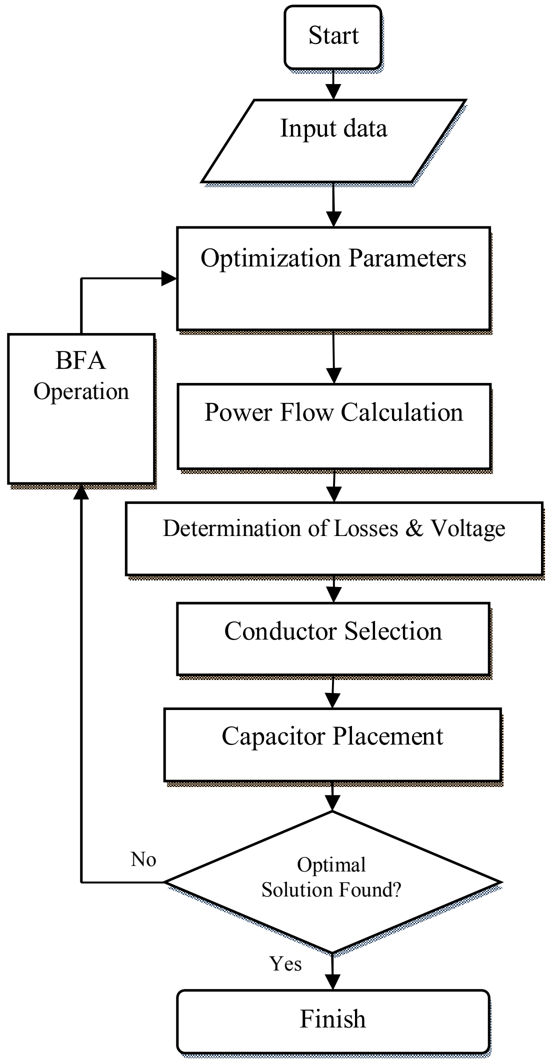

Figure 3: Flowchart of the proposed method

BACTERIAL FORAGING ALGORITHM (BFA)

Natural selection tends to eliminate animals with poor foraging strategies and favor the propagation of genes of those animals that have successful foraging strategies [15]. The Escherichia coli (E. coli) bacteria that are present in our intestines also undergo these foraging strategies. The social foraging behavior of E. coli bacteria has been used to solve optimization problems. The optimization in BFA comprises the following process: chemo taxis, swarming, reproduction, elimination and dispersal the chemo taxis is the activity that bacteria gathering to nutrient-rich area naturally. The characteristic of E. coli bacteria is: the diameter is 1μm, the length is 2μm, and under appropriate conditions can reproduce (split) in 20 min. The move of the E. coli is done with flagellum [21,22]. An E. coli bacterium alternates between running and tumbling. The flow chart of proposed method is depicted in Figure 4. At down, the E. coli bacterium is is depicted in Figure 5.

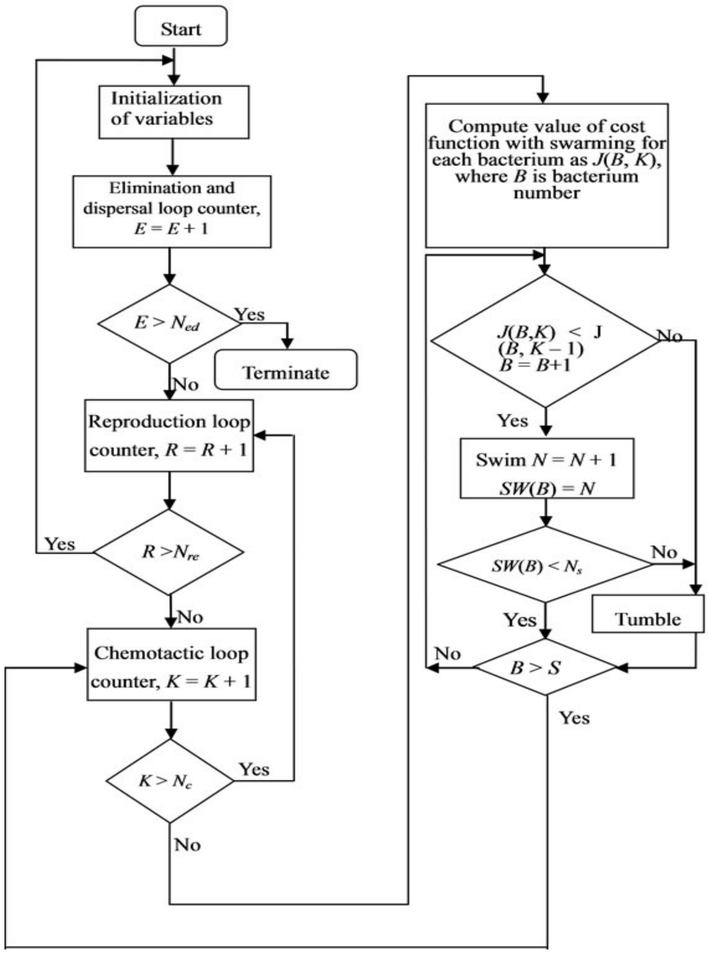

Figure 4: Flowchart of the proposed BFA algorithm

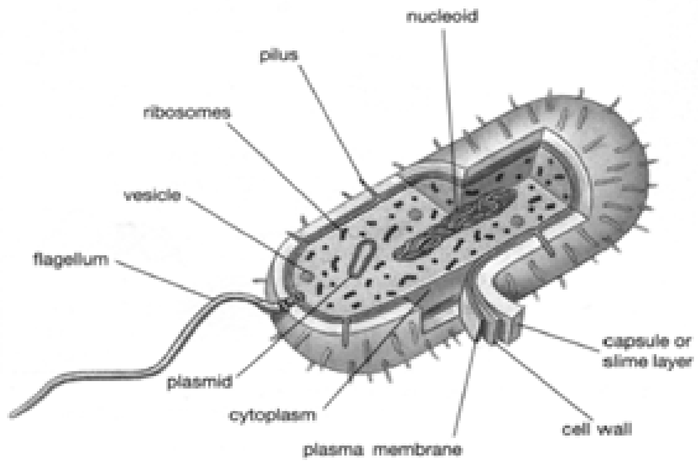

Figure 5: An E. coli Bacterium

Tests and Results

To study the proposed method, actual power network of Zafar feeder of Kerman Province, Iran is simulated in MATLAB. Figure6 illustrates the single-line diagram of this network. The base values of the system are taken as 20kV and 20MVA. The details of the distribution conductors are given in table 1. The system consists of 60 distribution transformers with various ratings. The details of the distribution transformers are given in table 2. The total connected load on the system is 2550 KVA and the peak demand for the year is 2120 KVA at a PF of 0.8 lag.

Figure6: Single-line diagram of actual power network of Zafar feeder of Kerman Province in Cymedist

Table 1: Conductor properties

Type	R [Ω/km]	X [Ω/km]	Cmax [A]	A [mm2]	Cost [Toman/m]
Hyena	0.1576	0.2277	550	126	2075
Dog	0.2712	0.2464	440	120	3500
Mink	0.4545	0.2664	315	70	2075

Table 2: Details of transformers in the system

Rating [KVA]	50	100	250
Number	5	9	6
No load losses [watts]	150	250	480
Impedance [%]	4.5	4.5	4.5

The other parameters used in computation process are: KP = 1.04 ($/kW); KE = 0.012 ($/kWh). The parameters used in BFA algorithm are: Number of Decate is 33; Population size is 100; Number of Empire 10; Revolution rate is 0.1. Also, loss factor, which represents adequately the energy losses for the load level in terms of the maximum power losses are selected.

The results of conductor selection are shown in Table 3.Initially, a load flow was run for the case study in both fundamental frequency and frequencies without installation of capacitor. Table 4 depicts the locations and capacity of capacitor banks using artificial bee colony algorithm. As it is clear, all the obtained values confines with all the considered constraints. The obtained penetration lever is 0.27, which is less than the assumed allowable value.

Table 3: Conductor selection results

Conductor Design Method	Type	Branch Number
Conventional	Hyena	From 1 to 26
	Dog	Rest of 68 branches
	Mink	----
BFA Based	Hyena	From 1 to 10
	Dog	From 11 to 23 34,35,36,37 From 44 to 58
	Mink	Rest of 68 branches

Table 4: Optimal place and capacity of capacitor banks

Location [#bus]	Capacity [Mvar]
9	0.15
10	0.35
27	0.45
48	0.35
61	0.5

The voltage profile in the system after BFA implementation is compared with Conventional conductor design and capacitor placement depicted in Figure7. The costs based on conductor selection and capacitor placement are compared in Table 5. The real power loss reductions are 15392.38579kW, which is approximately 8.5% in compare with the Conventional design for BFA respectively.

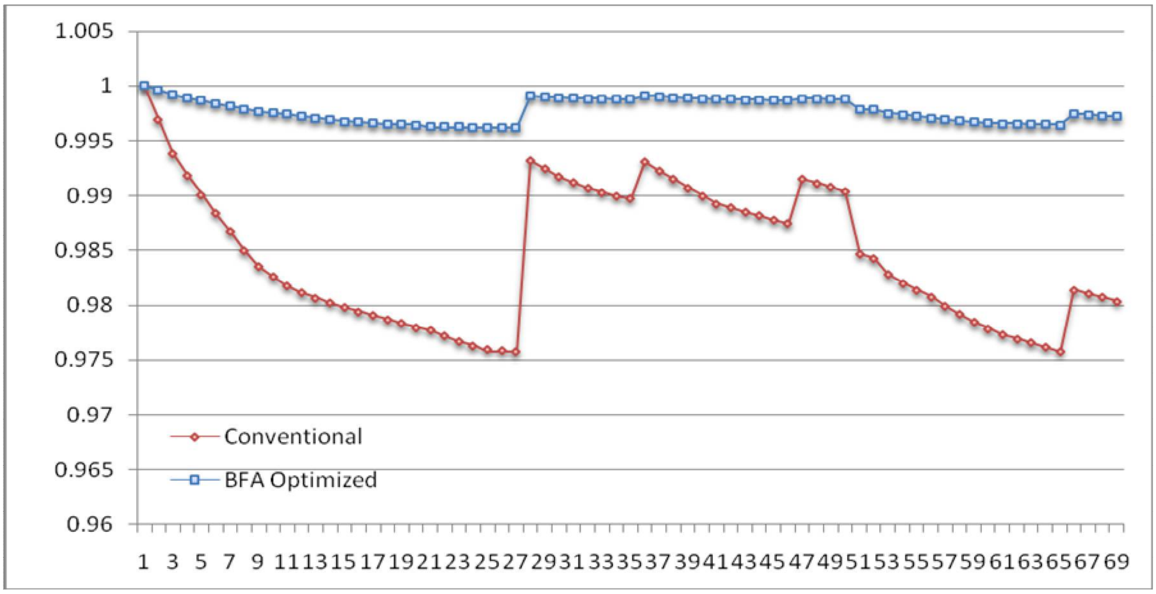

Figure7: Voltage profiles of 69-bus system

Table 8: Obtained Loss results

Method	Total Loss [KW]
Network Conventional	31153.244
Network BFA Optimized	18892.39

CONCLUSION

In this paper, the conductor selection has been incorporated in the conventional optimal capacitor placement. By making a new objective function and solving the optimization problem by BFA method, the size and place of the capacitors and the conductors has been defined. The method has been applied to a sample radial network and the results show the reduction of total costs in addition to the power loss reduction. According to the results, the bus voltages of the ending buses are in the permissible limits. The real power loss reductions are 606.7364 kW, which is approximately 5.6% in compare with the Conventional design for BFA respectively.

REFERENCES

1. Mahdi Mozaffari Legha, "Determination of exhaustion and junction of in distribution network and its loss maximum, due to geographical condition", MS.c Thesis; Islamic Azad University, Saveh Branch, Markazi Province, Iran; pp. 1-300, Aug 2011.
2. [2] Mahdi Mozaffari Legha, Rouhollah Abdollahzadeh, Ardalan Zargar, Mohammad Mozaffari Legha,, "Cocnductor Size Selection in Planning of Radial Distribution System for Productivity Improvement Using Imperialist Compotitive Algorithm", International Journal on Technical and Physical Problems of Engineering (IJTPE), Issue 15, Vol. 5, No. 2, June 2013, pp. 65-69.
3. [3] Ng H.N., Salama M.M.A. and Chikhani A.Y (2000), "DG allocation by approximate reasoning: fuzzy DG placement", IEEE Transactions on Power Delivery, vol. 15, No. 1, pp. 393-398.
4. Ji-Pyng Chiou et al (2006), "DG placement in large scale distribution system using variable scaling hybrid differential evolution", Electric Power and Energy Systems, vol. 28, pp.739-745.
5. R. S. Rao, "Optimal conductor selection for loss reduction in radial distribution systems using differential evolution," Int. J. Eng. Sci. Technol., vol. 2, no. 7, pp. 2829–2838, Jul. 2010.
6. S. Mandal and A. Pahwa, "Optimal selection of conductors for distribution feeders," IEEE Trans. Power Syst., vol. 17, no. 1, pp. 192–197, 2002.

7. M. J. Rider, M. Lavorato, R. Romero, "Optimal Conductor Size Selection and Reconductoring in Radial Distribution Systems Using a Mixed-Integer LP Approach", Power Systems, IEEE Transactions on,(doi: 10.1109/TPWRS.2012.2201263),2012
8. Chiradeja, Ramkumar , " An Approach to quantify the Benefits of Distrributed Generation Systems", IEEE trans. On Energy Conversion, Vol. 19, Dec 2004, pp 764 – 773.
9. Mahdi Mozaffari Legha, Moein khosravi, Mohammad Hossein Armand, Mahdiyeh Azh,, "Optimization of Location and Capacity DGs Using HPSO Approach Case Study on the Electrical Distribution Network of north Kerman Province", Middle-East Journal of Scientific Research, pp. 461-465, 2013.
10. Mahdi Mozaffari Legha,; "Optimal Conductor Selection of Radial Distribution Networks Using GA Method" CIRED Regional – Iran, Tehran, 13-14 Jan 2013; Paper No: 12-F-500-0320.
11. J. L. Bala, P. A. Kuntz, M. Tayor (1995), "Sensitivity-based optimal DG placement on a radial distribution feeder", Proc. Northcon 95, IEEE Technical Application Conf., pp. 225230
12. M. Vahid, N. Manouchehr, S. D. Hossein, and A. Jamaleddin, "Combination of optimal conductor selection and capacitor placement in radial distribution systems for maximum loss reduction" in Proc. 2009 IEEE Int. Conf. Industrial Technology, Gippsland, Australia, Feb. 10–13, 2009, pp. 01–05
13. Mahdi Mozaffari Legha, Marjan, Chiradeja, Ramkumar , " An Approach to quantify the Benefits of Distrributed Generation Systems", IEEE trans. On Energy Conversion, Vol. 19, Dec 2004, pp 764 – 773.

CITATION OF THIS ARTICLE

Mahdi Mozaffari L, Laya Amiri D, Seyedeh S H, Morteza P. Combination of Optimal Conductor Selection and Capacitor Placement in Radial Distribution Systems Using BFA Method. Bull. Env. Pharmacol. Life Sci., Vol 3 [9] August 2014: 28-36

