

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

Mahdi Mozaffari Legha^{1,a}, Farzaneh Ostovar^{2,b}, Mohammad Mozaffari Legha²

¹ Department of Power Engineering, Shadegan Branch, Islamic Azad University, Shadegan, Iran

² Department of Power Engineering, Shadegan Branch, Islamic Azad University, Shadegan, Iran

³ Department of Power Engineering, Kerman Branch, Islamic Azad University, Kerman, Iran

Mozaffari.m@shirazu.ac.ir^a; Farzaneh.ostovar@yahoo.com^b; Mozaffari50@gmail.com^c

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: PSO Algorithm, Radial Distribution Systems, Loss Reduction, Capacitor placement, Conductor Selection.

الجمع بين موصل الأمثل واختيار وتنسيب المكثفات في أنظمة توزيع شعاعي عن طريق الطريقة PSO

مهدي مظفرى لقا¹، فرزانه استوار²، محمد مظفرى لقا³

¹ قسم الهندسة الكهربائية، كلية الهندسة، شعبة شادكان، جامعة آزاد الإسلامية، شادكان، إيران

² قسم الهندسة الكهربائية، كلية الهندسة، شعبة كerman، جامعة آزاد الإسلامية، كerman، إيران

Mozaffari.m@shirazu.ac.ir^a; Farzaneh.ostovar@yahoo.com^b; Mozaffari50@gmail.com^c

الملخص

في هذه الورقة يقدم نهجا لأفضل المواقع والتحجيم من البنوك مكثف ثابت وأيضا اختيار موصل الأمثل في شبكات التوزيع شعاعي لغرض التقليل من الخسائر الاقتصادية وتعزيز الجهد. يتضمن دالة الهدف تكلفة الخسائر السلطة، لمحة الجهد والبنوك مكثف ثابت وأيضا نوع من اختيار موصل. وتشمل القيود الحد الجهد، والحد الأقصى المسموح به من حمل التيار الموصلات، وحجم المكثفات المتاحة ونوع من الموصلات. يتم حل المشكلة الأمثل من قبل الإمبريالية طريقة خوارزمية تنافسية ويتم تحديد حجم وموقع مكثف المصارف ونوع من الموصلات. للتدليل على صحة الخوارزمية المقترحة، تتم محاكاة الكمبيوتر من على شبكة الكهرباء الفعلية للمدينة كerman، وتعرض إيران ونتائج المحاكاة ومناقشتها.

1. 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 (Mahdi Mozaffari Legha et al, 2012).

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. (Baghzouz and Ertem, 1990) proposed the concept that the size of capacitor banks was considered as a continuous variable. (H. Ng et al, 2000) proposed the capacitor placement problem by using fuzzy approximate reasoning. (Ji Pyng Chiou et al, 2006) 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 (R. S. Rao, 2010). They presents models to represent feeder cost, energy loss and voltage regulation as a function of a conductor cross-section. In (M. Vahid, et al, 2009), the conductor size selection performed with consideration of financial and engineering criteria in the feeder. In (G. J. Anders et al, 1993) and (M. Ponnavaikko et al, 1982) the CSS problem is solving using heuristic methods. Reference

(G. J. Anders et al, 1993) 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 (M. Ponnavaikko et al, 1982) 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 (S. Mandal et al, 2002), a mixed integer linear model for the problem of conductor selection size in radial distribution systems is presented.

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, PSO 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.

2. PROBLEM FORMULATIONS

2.1. 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 (S. Mandal and et al).

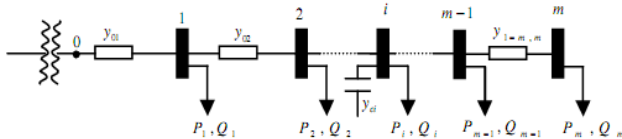


Fig. 1: Single line diagram of a radial distribution feeder

Notation:

$Y_{i,i+1}=1/(R_{i,i+1}+jX_{i,i+1})$; 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

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

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 (M. J. Rider et al, 2012):

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

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

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

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); (M. J. Rider et al, 2012).

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

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.

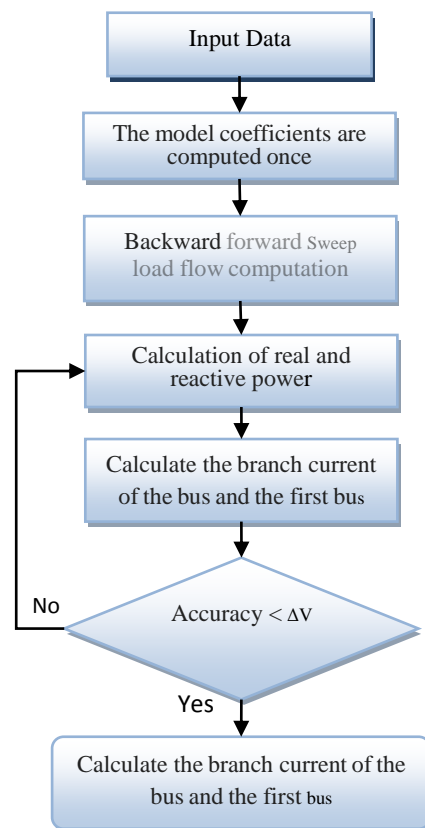


Figure 1: Flowchart of the Backward-Forward sweep method

2.2. 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

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

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

$$f_1 = K_p \times P_T^{\text{LOSS}} + \sum_i^c (K_{cf} + K_i^c Q_i^c) \quad (6)$$

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

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

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

$$f_2 = CE(i, c) + \gamma * A(c) * \{C(c) + L(i)\} \quad (8)$$

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,

$$CE(i, c) = P L(i, c) * \{K_p + K_E * L_{SF} * T\} \quad (9)$$

Where K_p is annual demand cost due to Power Loss ($\$/\text{kW}$), K_E is annual cost due to Energy Loss ($\$/\text{kWh}$), 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 ($\$/\text{km}$), $A(c)$ is cross-sectional area of c type conductor and $L(i)$ is length of branch i (km).

3. 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.

$$F = f_1 + f_2 \quad (11)$$

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

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

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.

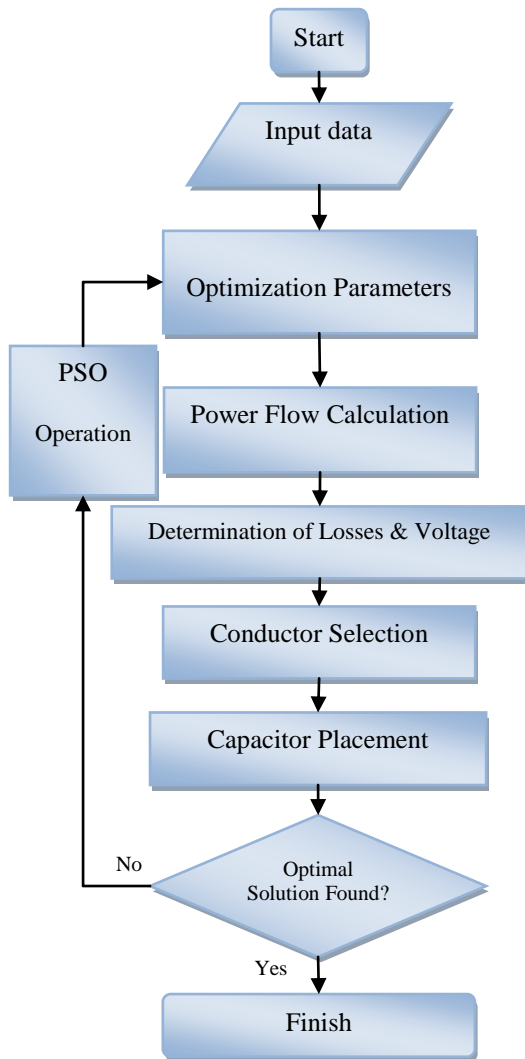


Figure 3: Flowchart of the proposed method

4. PSO Algorithm

PSO is a population based stochastic optimization technique developed by Eberhart and Kennedy in 1995 [12-13]. The PSO algorithm is inspired by social behavior of bird flocking or fish schooling. The system is initialized with a population of random solutions and searches for optima by updating generations. However, unlike GA, PSO has no evolution operators such as crossover and mutation. In PSO, the potential solutions, called particles, fly through the problem space by following the current optimum particles. Compared to GA, the advantages of PSO are that PSO is easy to implement and there are few parameters to adjust. PSO has been successfully applied in many areas [14]. The

standard PSO algorithm employs a population of particles. The particles fly through the n-dimensional domain space of the function to be optimized. The state of each particle is represented by its position $x_i = (x_{i1}, x_{i2}, \dots, x_{in})$ and velocity $v_i = (v_{i1}, v_{i2}, \dots, v_{in})$, the states of the particles are updated. The three key parameters to PSO are in the velocity update equation (13). First is the momentum component, where the inertial constant w , controls how much the particle remembers its previous velocity [14]. The second component is the cognitive component. Here the acceleration constant $C1$, controls how much the particle heads toward its personal best position. The third component, referred to as the social component, draws the particle toward swarm's best ever position; the acceleration constant $C2$ controls this tendency. The flow chart of the procedure is shown in Figure 4.

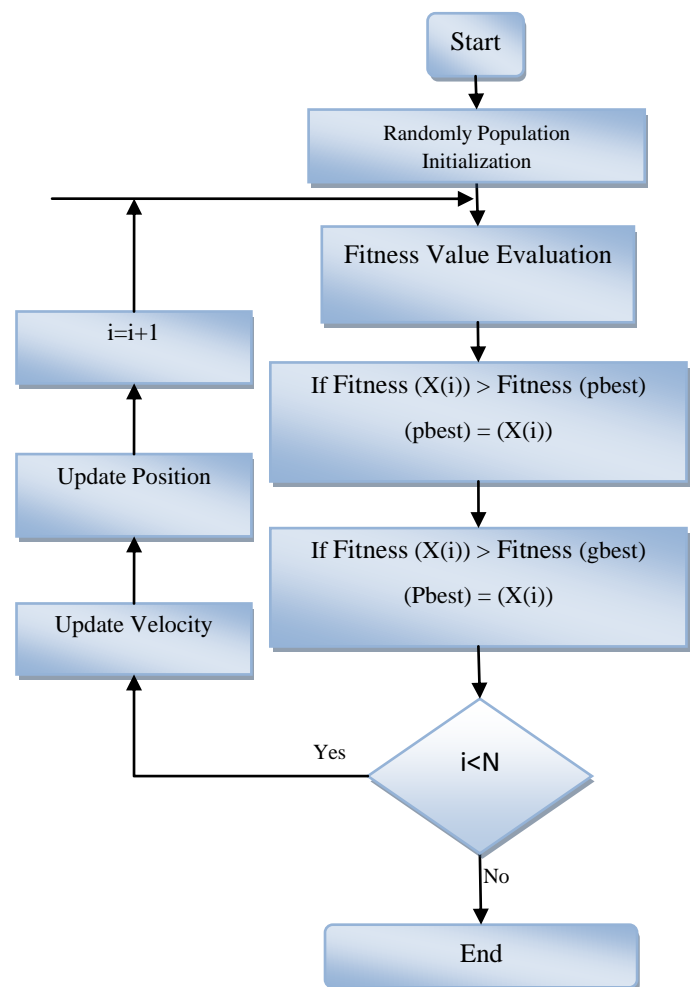


Figure 4: Flowchart of the proposed PSO algorithm

5. Tests and Results

To study the proposed method, actual power network of Kosar feeder of Kerman Province, Iran is simulated in Cymedist. Figure 5 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.

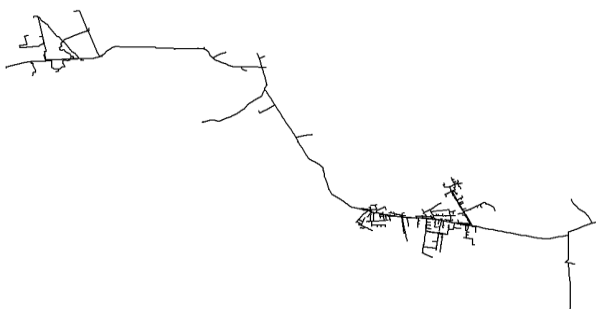


Figure 5: Single-line diagram of actual power network of Kosar feeder of Kerman Province in Cymedist

Table 1: Conductor properties

Type	R [Ω/km]	X [Ω/km]	Cma x [A]	A [mm2]	Cost [Toman/ m]
Hyena	0.157 6	0.227 7	550	126	2075
Dog	0.271 2	0.246 4	440	120	3500
Mink	0.454 5	0.266 4	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 PSO

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	----
PSO 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]
7	0.1
13	0.15
31	0.15
54	0.35
68	0.25

The voltage profile in the system after PSO implementation is compared with Conventional conductor design and capacitor placement depicted in Figure 6. 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 PSO respectively.

Figure 6: Voltage profiles of 69-bus system

Table 8: Obtained Loss results

Method	Total Loss [KW]
Network Conventional	32453.24452
Network PSO Optimized	15392.38579

6. 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 PSO 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 PSO respectively.

7. References

[1] M. Mozaffari Legha, (2011) 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.

[2] Mahdi Mozaffari Legha, Farzaneh Ostovar, “Analysis and Reconductoring of Overhead Conductors with Considering aging for Radial Distribution Systems Using Imperialist competitive Algorithm”, International Journal of Pure and Applied Sciences and Technology, Vol. 20, No. 1, January 2014, pp. 1-8.

[3] Mahdi Mozaffari Legha, Rouhollah Abdollahzadeh, Ardalan Zargar, Mostafa Shadfar. “Effective method for optimal allocation of distributed generation units in radial electric power systems by genetic algorithm and imperialist competitive algorithm”, International Journal on Technical and Physical Problems of Engineering (IJTPE), Issue 15, Vol. 5, No. 2, pp. 70-74, June 2013.

[4] 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.

[5] Mahdi Mozaffari Legha and et al, ”A new hybrid particle swarm optimization approach for sizing and placement enhancement of distributed generation” IEEE Conference, 2155-5516; Pages 1277 - 1281.

[6] 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.

[7] Mahdi Mozaffari Legha, Marjan Tavakoli, Farzaneh Ostovar, Milad Askarihashemabadi, “Capacitor Placement in Radial Distribution System for improve network efficiency Using Artificial Bee Colony“, International Journal of Engineering Research and Application, Vol. 3, Issue 6, Nov-Dec 2013, pp.01-05

[8] 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.

[9] Mahdi Mozaffari Legha, Houman Gadari1,,”Technical and Economical Evaluation of Solar Plant for Electricity Supply Anar City Residential Customers”, Middle-East Journal of Scientific Research, pp. 455-460, 2013.

[10] M. Vahid, N. Manouchehr, S. D. Hossein, and A. Jamaledin, “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.
- [11] G. J. Anders, M. Vainberg, D. J. Horrocks, S. M. Foty, J. Motlis, and J. Jarnicki, “Parameters affecting economic selection of cable sizes,” *IEEE Trans. Power Del.*, vol. 8, no. 4, pp. 1661–1667, Oct. 1993.
- [12] M. Ponnaivaikko and K. S. Prakasa, “An approach to optimal distribution system planning through conductor gradation,” *IEEE Trans. Power App. Syst.*, vol. PAS-101, no. 6, pp. 1735–1742, Jun. 1982.
- [13] S. Mandal and A. Pahwa, “Optimal selection of conductors for distribution feeders,” *IEEE Trans. Power Syst.*, vol. 17, no. 1, pp. 192–197, 2002.
- [14] Z. Wang, H. L. Yu, X. Wang, and H. Song, “A practical approach to the conductor size selection in planning radial distribution systems,” *IEEE Trans. Power Del.*, vol. 15, no. 1, pp. 350–354, Jan. 2000.
- [15] D. Karaboga, B. Basturk (2007), “A powerful and efficient algorithm for numerical function optimization: artificial bee colony (ABC) algorithm”, *Journal of Global Optimization*, vol. 39, pp. 459-471.
- [16] D. Karaboga, B. Basturk (2008), “On the performance of artificial bee colony (ABC) algorithm”, *Applied Soft Computing*, vol. 8 pp. 687-697.
- [17] B. Basturk, D. Karaboga (2006), “An artificial bee colony (ABC) algorithm for numeric function optimization”, *IEEE Swarm Intelligence Symposium 2006*, May 12-14, Indianapolis, IN, USA.
- [18] H.A. Shayanfar, H. Shayeghi, A. Jali, “Takagi-
- [19] Sugeno Fuzzy Parallel Distribution Compensation Based Three-Area LFC Design”, *International Journal on Technical and Physical Problems of Engineering (IJTPE)*, Issue 8, Vol. 3, No. 3, pp. 55-64, September 2011.
- [20] 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
- [21] F. Mendoza, D. Requena, J. L. Bernal-Agustin, and J. A. Dominguez-Navarro, “Optimal conductor size selection in radial power distribution systems using evolutionary strategies,” in Proc. IEEE/PES Transmission & Distribution 2006 Latin América, Venezuela, 15–18, 2006, pp. 01–05.
- [22] R. Ranjan, A. Chaturvedi, P. S. Solanki, and D. Das, “Optimal conductor selection of radial distribution feeders using evolutionary programming,” in Proc. 2003 IEEE Region 10 Conf. Convergent Technologies for the Asia-Pacific (TENCON 2003), Bangalore, India, 15–17, 2003, vol. 1, pp. 456–459.
- [23] Mahdi Mozaffari Legha, Farzaneh Ostovar, “An Imperialist Competitive Algorithm for Siting and Sizing of Distributed Generation in Radial Distribution Network to Improve Reliability and Losses Reduction” *Iraqi Journal for Electrical and Electronic Engineering (IJEEE)*, Vol.9 No.1, 2013, pp. 59-67.
- [24] Mahdi Mozaffari Legha, Hassan Javaheri, Mohammad Mozaffari Legha, “Optimal Conductor Selection in Radial Distribution Systems for Productivity Improvement Using Genetic Algorithm” *Iraqi Journal for Electrical and Electronic Engineering (IJEEE)*, Vol.9 No.1, 2013, 29-36.
- [25] N. Medina, M.M. Qi, L. Butler-Purry, K.L. A Three Phase Load Flow Algorithm for Shipboard Power Systems (Sps), 2003.
- [26] Web site Electrical Power Engineering Specialists, REPORTs, 2014. Available at: <<http://www.drmozaffarilegha.com.com>> [accessed 01.01.2014]
- [27] Mahdi Mozaffari Legha, “Optimal Conductor Selection of Radial Distribution Networks Using GA Method” *CIREC Regional – Iran*, Tehran, 13-14 Jan 2013; Paper No: 12-F-500-0320.
- [28] 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.
- [29] Mahdi Mozaffari Legha, Rouhollah Abdollahzadeh, Ardalan Zargar, Mostafa Shadfar. “Effective method for optimal allocation of distributed generation units in radial electric power systems by genetic algorithm and imperialist competitive algorithm”, *International Journal on Technical and Physical Problems of Engineering (IJTPE)*, Issue 15, Vol. 5, No. 2, pp. 70-74, June 2013.
- [30] 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.
- [31] O. Amanifar, M.E. Hamedani Golshan, “Optimal Distributed Generation Placement and Sizing for Loss THD Reduction and Voltage Profile Improvement in Distribution Systems Using Particle Swarm Optimization and Sensitivity Analysis”, International Journal on Technical and Physical Problems of Engineering (IJTPE), Issue 7, Vol. 3, No. 2, pp. 47-53, March 2011.
- [32] T. Gönen, Electric Power Distribution Systems Engineering. New York: McGraw-Hill, 1986.