

A New Method for Optimal Reconstruction of Radial Distribution Network; Case Study in KERMAN

Mahdi Mozaffari Legha*,¹ Alireza Nasiripor,²

¹Department of Power Engineering, Institute of Higher Education Javid, Jiroft, Iran.

²Jiroft Medical Sciences, Iran.

*Corresponding Author: **Mahdi Mozaffari Legha**

Abstract: The availability of an adequate amount of electricity and its utilization is essential for the growth and development of the country. Development of distribution systems result in higher system losses and poor voltage regulation. Consequently, an efficient and effective distribution system has become more urgent and important. In medium voltage electrical distribution networks, reformed the loss reduction is very important and certainly in line with this, system engineering issue and use of proper equipment, a good work has been done. Hence proper selection of conductors in the distribution system is important as it determines the current density and the resistance of the line. In this paper examines the use of different evolutionary algorithm, imperialist competitive algorithm (ICA) to optimal branch optimization Reconstruction of aging of overhead conductors in t radial distribution systems with objective function to reduce the sum of capital cost and power loss cost and voltage deviation. This algorithm is easy to programming and needs no approximation of actual condition. The proposed method can be applied for optimal planning of radial electric distribution systems. Effectiveness of the proposed method is shown by case study in a radial network.

Keyword: Optimization, Reconstruction, aging of overhead conductors, Imperialism Competitive Algorithm (ICA), Radial Distribution Networks, back/forward sweep, Voltage profile, Loss Reduction.

Introduction

The main objective of an electrical distribution system (EDS) is to provide 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]. 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) [2]. Dynamic programming approach was utilized to solve the CSS problem in [3].

The close propinquity of distribution

network to the consumers of electricity has made it a necessity to explore the area of practical planning of distribution system. Because of the growing effort to reduce system losses, many papers have been published in recent years referring to optimal distribution planning, but in all these attempts, its significant sub problems of optimal conductor size selection, optimal place of capacitors to obtain minimum possible loss, still need to be further studied. Some articles have been published dealing with optimal planning of distribution networks, in general have focused on reducing cost through optimizing the conductor profile, capacitor cost, and in some cases cost of losses. But in these all, increasing rate of load for future years is not considered. They presents models to represent feeder cost, energy loss and voltage regulation as a function of a conductor cross-section. In [4], the conductor size selection

performed with consideration of financial and engineering criteria in the feeder. In [5] and [6] the CSS problem is solve using heuristic methods. Reference [5] 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 [6] 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 some studies, a linear approximation in the calculation of power losses or voltage regulation is considered [7], while other approximates the load as a constant current model [3]. In [7], a mixed integer linear model for the problem of conductor selection size in radial distribution systems is presented.

In this paper examines the use of different evolutionary algorithm, imperialist competitive algorithm (ICA) to optimal branch optimization Reconstruction of aging of overhead conductors in radial distribution systems with objective function to reduce the sum of capital cost and power loss cost and voltage deviation. This algorithm is easy to programming and needs no approximation of actual condition. The proposed method can be applied for optimal planning of radial electric distribution systems. Effectiveness of the proposed method is shown by case study in a radial network.

Problem Formulation

Objective Function

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 and reliability while maintaining the voltages at different buses within the limits. In this case, the objective function with conductor j in branch i is written as

$$\text{Min } f(i,j) = w_1 * CE(i,j) + w_2 * DCI(i,j) \quad (1)$$

In Equation (1) $CE(i,j)$ is the Cost of Energy Losses $DCI(i,j)$ is Depreciation on Capital Investment of j conductor type of i -th branch, n is buss number, i is the branch number and w is the weighting factor[13]. In Equation (2) and (3), V_{min} for any bus= 0.95 and V_{max}

for any bus= 1.05; I_{max} for any line is According to table1. The annual cost of loss in branch i with conductor type k is,

$$CE(i,j) = P L(i,j) * \{K_P + K_E * \beta * T\} \quad (2)$$

In Equation (4) K_P is annual demand cost due to Power Loss (\$/kW), K_E is annual cost due to Energy Loss (\$/kWh), β 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). Depreciation on capital investment is given as

$$DCI(i,j) = a * A(j) * \{C_j + L_i\} \quad (3)$$

Where a is Interest and depreciation factor, C_j is cost of type conductor (\$/km), $A(j)$ is cross-sectional area of j type conductor and L_i is length of branch i (km).

Constraints

Voltage: the voltage drop at every node in the feeder must be less than maximum allowable value, means:

$$V_{min} \leq |V_i| \leq V_{max} \quad i=1, 2, 3, \dots, n \quad (4)$$

Current: Current flowing through section j with a given type of conductor (conj) should be less than the maximum allowable current carrying capacity of conj conductor, i.e.

$$|I_l| \leq I_{max} \quad l=1, 2, 3, \dots, n-1 \quad (5)$$

Power Flow Analysis Method

The method proposed for solving distribution power flow analysis is Backward-Forward Sweep method which is an iterative means to solving the load flow equations of radial distribution systems which has two steps the Backward sweep, which updates currents using Kirchoff's Current Law (KCL), and the Forward sweep, which updates voltage using voltage drop calculations [12].

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 [12]. The Backward-Forward sweep Flowchart of the method depicted in Figure 1[1, 12].

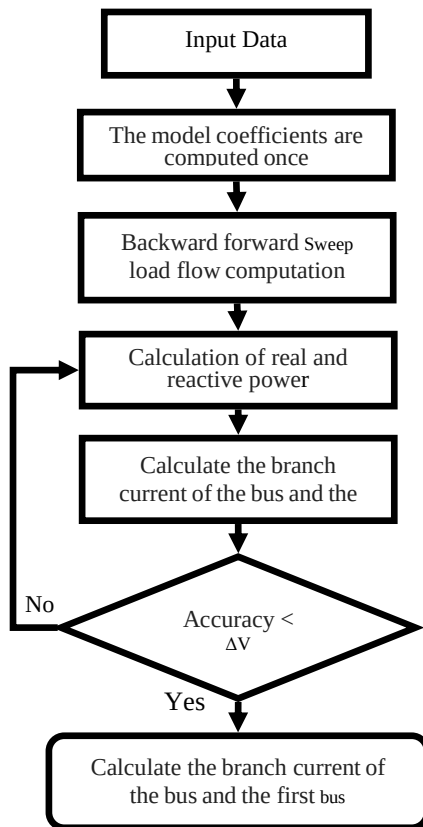


Figure 1: Flowchart of the Backward-Forward sweep method

Imperialist Competitive Algorithms

ICA mimics the social-political process of imperialism and imperialistic competition. ICA starts with an initial population of individuals, each called a country. Some of the best countries are selected as imperialists and the rest form colonies which are then divided among imperialists based on imperialists' power. After forming the initial empires, competition begins and colonies move towards the irrelevant imperialists.

During competition, weak empires collapse and powerful ones take possession of more

colonies. At the end, there exists only one empire while the position of imperialist and its colonies are the same [15]. The process ICA is depicted in Figure 3-5 and flow chart of proposed ICA is depicted in Figure 6.

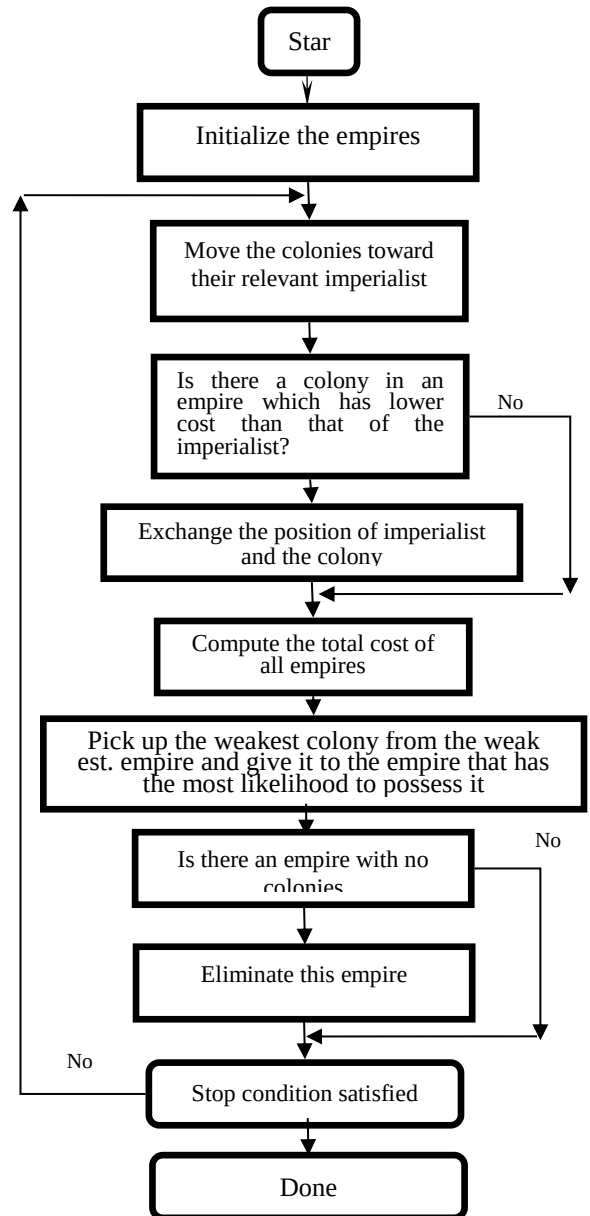


Figure 6: Flowchart of the proposed ICA algorithm

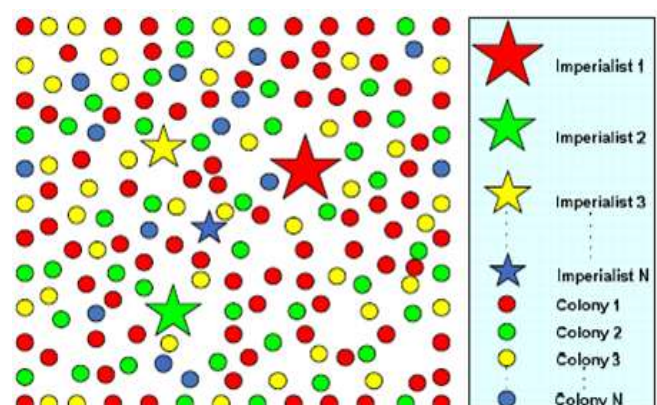


Figure 3: Creation of initial empires

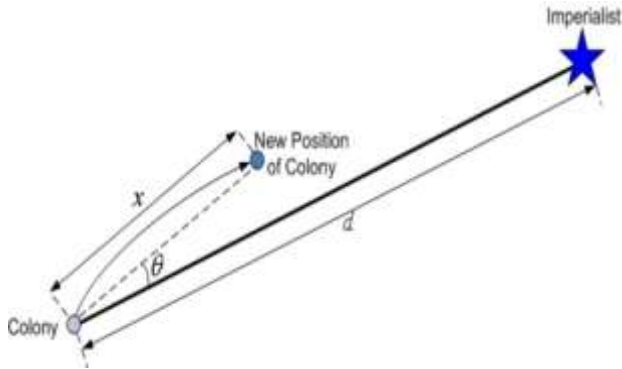


Figure 4: Colony movement toward his empires

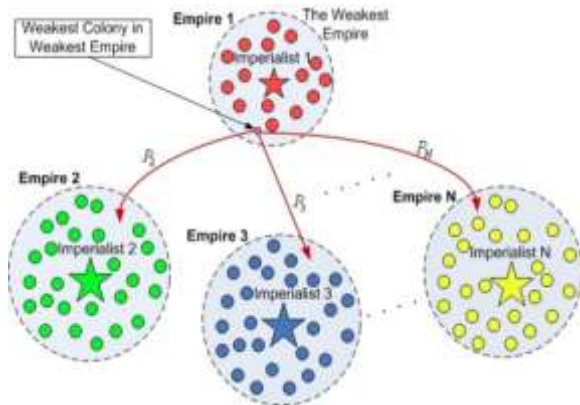


Figure 5: Take possession of the weakest colony and empires

Steps of Proposed Analysis

From the construction phase to the operational phase of destruction are affected by a variety of each of these factors can cause the kind of damage such as wear and finally decided to enter the power network or utility side. Evaluation conductors of electrical distribution networks are a very important role in asset management systems. In this paper feeder conductors used in networks Kosar, Zafar Substation, with 18.74 Km of the Kerman area Inclusive conductors such as Hayna ($A=126 \text{ mm}^2$), Doug ($A=120 \text{ mm}^2$) and Mink ($A=70 \text{ mm}^2$). Also information of aging conductors was collected 2 m.

According to the information network each section was determined by the electricity distribution network. After collection, the conductors in the cable and wire industry, LAB Wire and cable Kerman conductor resistance and corrosion rate measurements were conductors. Conductor resistance test results for each of the years indicated in Table 1 also The properties of the new conductors used in the analysis of this system are given in Table 2. The flow chart of proposed method is depicted in Figure 2.

Table 1: Aging Conductors properties

A [mm^2]	R [Ω/km]	Year
70	0.4545	new
70	0.461678	10
70	0.465765	20
70	0.505475	40
120	0.2712	new
120	0.278378	10
120	0.282465	20
120	0.322175	40
126	0.1576	new
126	0.181409	10
126	0.203974	20
126	0.468	40

Table 2: New Conductor Properties

Type	R [$\Omega/\text{k m}$]	X [$\Omega/\text{k m}$]	Cma x [A]	A [mm^2]	Cost [Toman/m]
Hyen a	0.1576	0.2277	550	126	4075
Dog	0.2712	0.2464	440	120	3500
Mink	0.4545	0.2664	315	70	2125

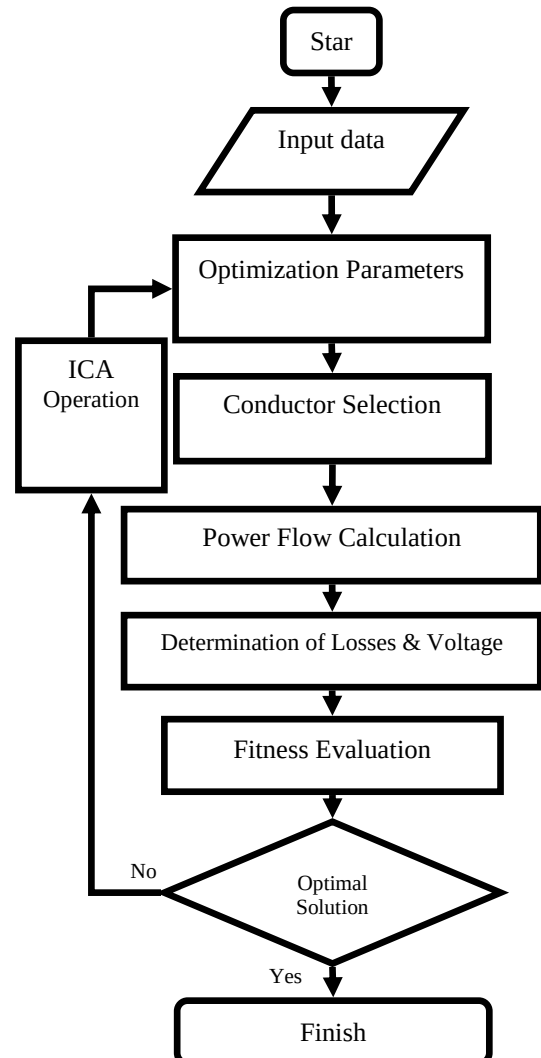


Figure 2: Flowchart of the proposed ICA algorithm

Computational Test

To study the proposed method, actual power network of Kosar feeder of Kerman Province, Iran. Simulations are carried out on 69-bus radial distribution network using ICA approach in order to show the accuracy as well as the efficiency of the proposed solution technique. The single line diagram for

proposed radial distribution systems is shown in Fig. 2. The initial data for load flow solution based on the Backward-Forward sweep are selected as: $V_{base}=20\text{kV}$ and $S_{base}=1000\text{kVA}$. The other parameters used in computation process are: $KP=1.04$ (\$/kW); $KE=0.012$ (\$/kWh).

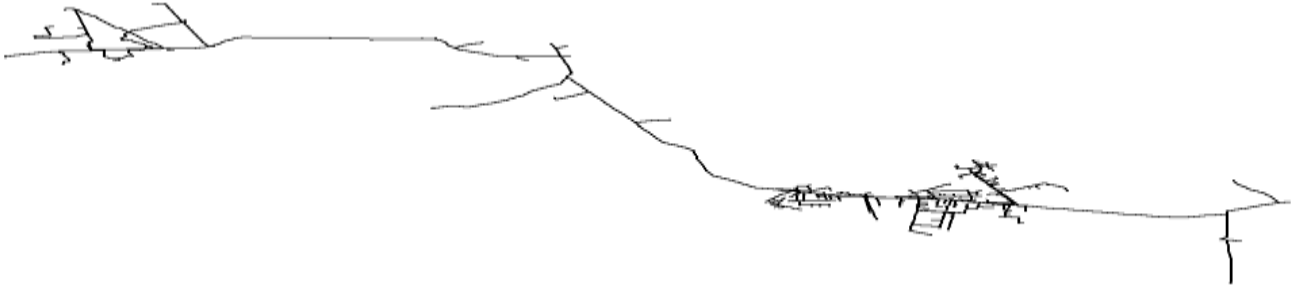


Figure 2: Single-line diagram of actual power network of Kosar feeder of Kerman Province in Cymedist

Table 1: Conductor Type

No.	Conductor Type	No.	Conductor Type	No.	Conductor Type	No.	Conductor Type
1	Hyena	18	Hyena	35	Dog	52	Dog
2	Hyena	19	Hyena	36	Dog	53	Dog
3	Hyena	20	Hyena	37	Dog	54	Dog
4	Hyena	21	Mink	38	Mink	55	Dog
5	Hyena	22	Mink	39	Mink	56	Mink
6	Hyena	23	Mink	40	Mink	57	Mink
7	Hyena	24	Mink	41	Mink	58	Mink
8	Hyena	25	Dog	42	Mink	59	Mink
9	Hyena	26	Dog	43	Mink	60	Mink
10	Hyena	27	Dog	44	Mink	61	Mink
11	Hyena	28	Dog	45	Mink	62	Mink
12	Hyena	29	Dog	46	Mink	63	Mink
13	Hyena	30	Dog	47	Mink	64	Mink
14	Hyena	31	Dog	48	Mink	65	Mink
15	Hyena	32	Dog	49	Mink	66	Mink
16	Hyena	33	Dog	50	Mink	67	Mink
17	Hyena	34	Dog	51	Mink	68	Mink

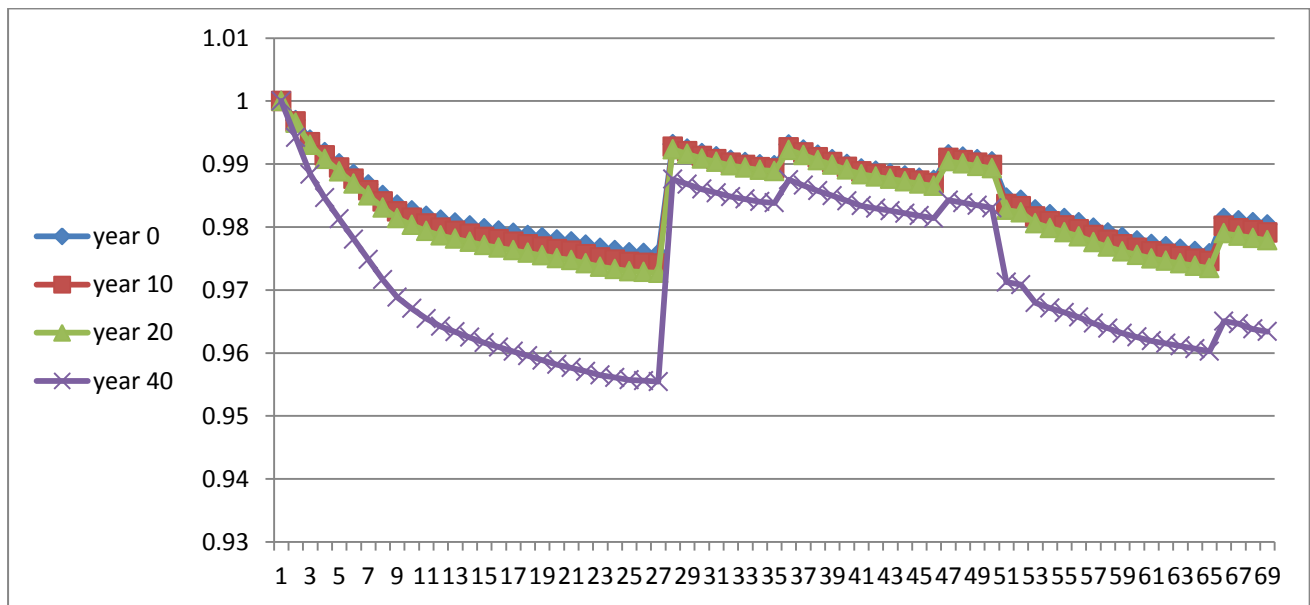
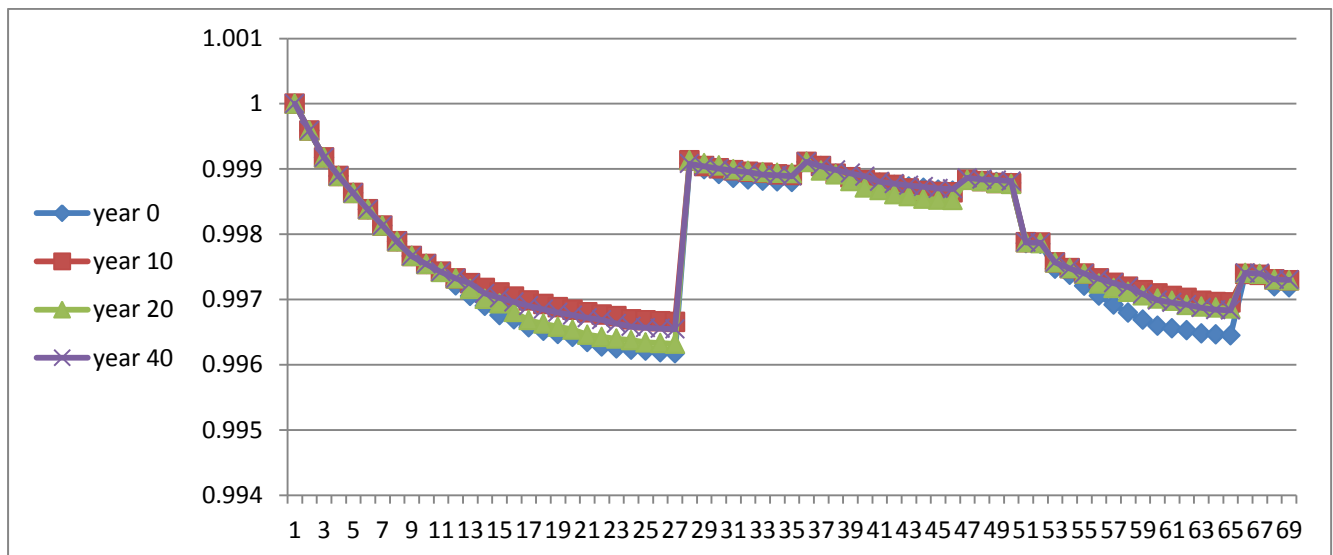
The parameter used in ICA algorithm are number of Decade is 33; Population size 100; Number of Empire 10; Revolution rate is 0.1, Also V_{min} for any bus= 0.95 and V_{max} for any bus= 1.05. Also, loss factor is 0.2, which represents adequately the energy losses for the load level in terms of the maximum power losses are selected. The results of conductor selection are shown in Table 2. The real power loss reaches from 44.5 MW to 17 KW for network with new (0) years old conductors using ICA method and the real power loss reaches from 50 MW to 14.5 KW

for network with 10 years old conductors using ICA method and the real power loss reaches from 55 MW to 15.8 KW for network with 20 years old conductors using ICA method and the real power loss reaches from 118.5 MW to 16.75 KW for network with 40 years old conductors using ICA method. The results of conductor selection for network with conductors aged 40 years old with ICA method is compared with Conventional are shown in Table 2.

Table 2: Conductor selection results

Conductor Design Method	Type	Branch Number
Conventional	Hyena	From 1 to 26
	Dog	Rest of 68 branches
	Mink	---
Reconductoring of network with conductors aged 40 years using ICA method	Hyena	From 1 to 13
	Dog	14,15,16,17,22,23,24,56,57
	Mink	Rest of 68 branches

The voltage profile in the system after ICA implementation for network with conductors aged new, 10, 20 and 40 years old design depicted in Figure 6 and the voltage profile in the system conventional for network with conductors aged new, 10, 20 and 40 years design depicted in Figure 7. Also The power loss each branch in the system after ICA implementation for network with conductors aged new, 10, 20 and 40 years old design depicted in Figure 8 and the power loss each branch in the system conventional for network with conductors aged new, 10, 20 and 40 years design depicted in Figure 9. The power loss for networks with conductors aged new, 10, 20 and 40 years old design depicted in Figure 10.


Figure 6: Voltage profile in the system conventional for network with conductors aged new, 10, 20 and 40 years

Figure 7: Voltage profile in the system after ICA for network with conductors aged new, 10, 20 and 40 years

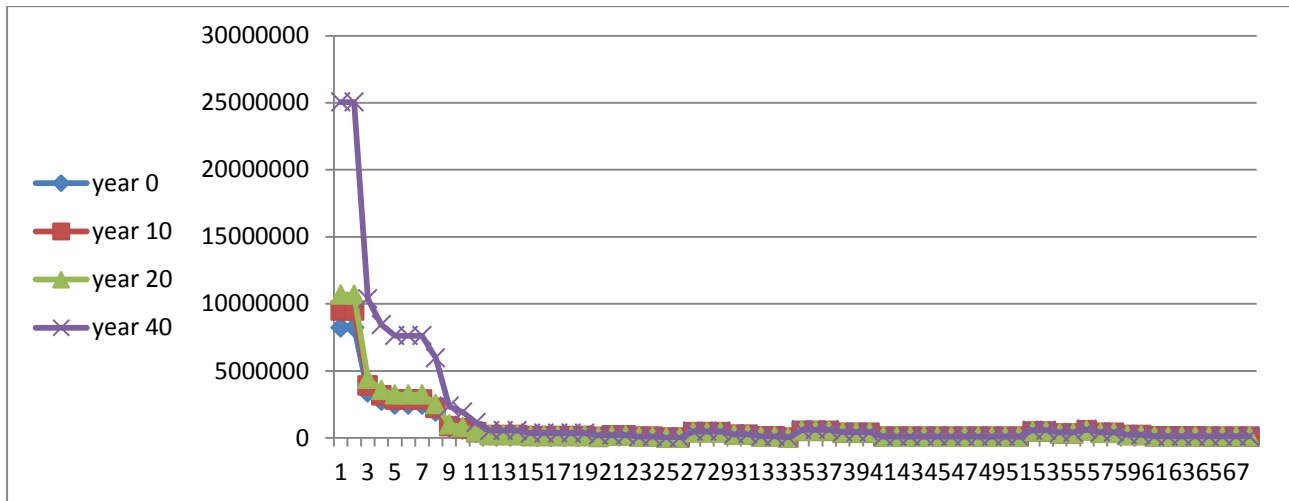


Figure 8: Power loss each branch in the system conventional for network with conductors aged new, 10, 20 and 40 years

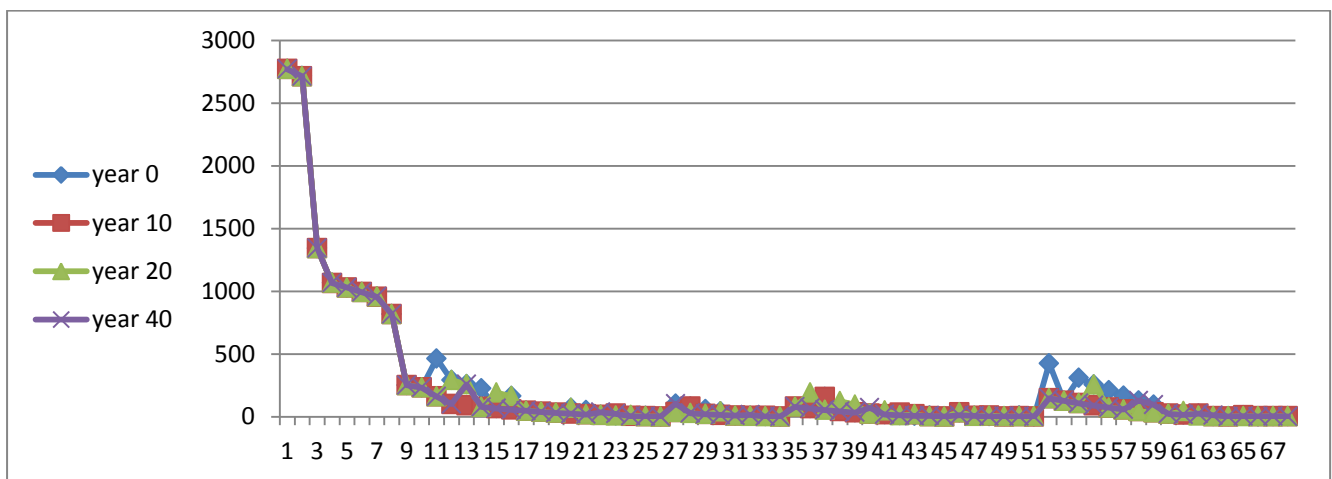


Figure 9: Power loss each branch in the system after ICA for network with conductors aged new, 10, 20 and 40 years

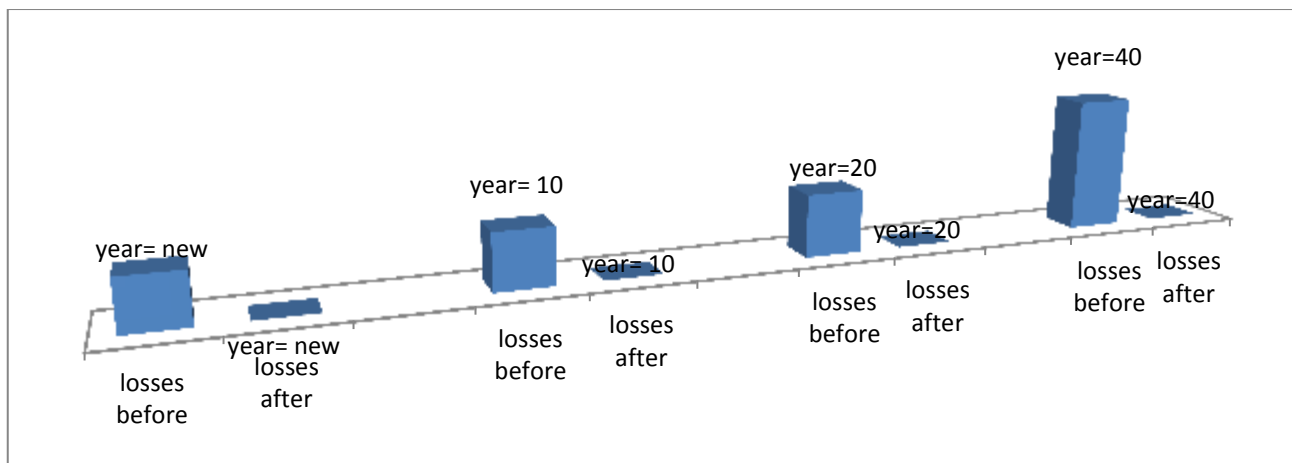


Figure 10: power loss for networks with conductors aged new, 10, 20 and 40 years old

Conclusion

Optimal selection of conductor type for planning radial distribution systems using evolutionary approaches is presented with the objective to minimize the overall cost of annual energy losses and depreciation on the cost of conductors in order to improve

productivity. The power losses, voltage magnitude, and current flow magnitudes are calculated using the Backward-Forward sweep method. The performance of the proposed evolutionary approaches Imperialism Competitive Algorithm (ICA),

in comparison with a conventional method is investigated using a case study in a radial network. The power loss reduction and voltage profile improvement has been

successfully achieved which demonstrate the effectiveness of the proposed approaches. The results offer potential of using ICA for improving plant productivity and economy.

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] M. Sharafi, H. Samet, Abdollah Kavousifard, Mahdi Sharafi, Mohammad Reza Rahmati (2013) "Optimal Conductor Selection of radial distribution networks using pso method" cired regional – Iran, Tehran, 12(E-500):0317.
- [3] M Ponnavaikko, KS Prakasa (1982) "An approach to optimal distribution system planning through conductor gradation," iee trans. Power App. Syst., PAS-101(6):1735-1742.
- [4] Mahmood Joorabian, Ehsan Afzalan; "Optimal Selection of Conductors Using Colonial Selection Algorithm (CSA) for productivity Improvement Radial Distribution Systems," 28th, Power System Conference - 2013 Tehran, Iran
- [5] Z Wang, HL Yu, X Wang, H. Song (2000) "A practical approach to the conductor size selection in planning radial distribution systems," IEEE Trans. Power Del., 15(1):350-354.
- [6] M. 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] MJ 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] F Mendoza, D Requena, JL Bernal-Agustin, JA Dominguez-Navarro (2006) "Optimal conductor size selection in radial power distribution systems using evolutionary strategies," in Proc. IEEE/PES Transmission & Distribution 2006 Latin América, Venezuela, 01-05.
- [9] R. Ranjan, A. Chaturvedi, P. S. Solanki, and D. Das (2003) "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, (1):456-459.
- [10] RS Rao (2010) Optimal conductor selection for loss reduction in radial distribution systems using differential evolution," Int. J. Eng. Sci. Technol., 2(7):2829-2838.
- [11] M Vahid, N Manouchehr, SD Hossein, A Jamaledin (2009) "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, P. 01-05.
- [12] N Medina, MM Qi, L Butler-Purry KL (2003) A Three Phase Load Flow Algorithm for Shipboard Power Systems (Sps).
- [13] T Gönen, Electric Power Distribution Systems Engineering. New York: McGraw-Hill, 1986.
- [14] DE Goldberg (1989) Genetic Algorithms in search, Optimization and Machine Learning.' Addison –Wesley, Reading MA.
- [15] E Atashpaz-Gargari, C Lucas (2007) Imperialist Competitive Algorithm: An Algorithm For Optimization Inspired By Imperialistic Competition'. IEEE Congre vol comput, 4661-7.
- [16] O Amanifar, ME Hamedani Golshan (2011) 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), 3(7):47-53.
- [17] HA Shayanfar, H Shayeghi, A Jali (2011) Takagi 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, P. 55-64.
- [18] Mahdi Mozaffari Legha, Rouhollah Abdollahzadeh Sangrood, Ardalan ZARGAR Raeiszadeh, Mohammad Mozaffari Legha (2013) A practical approach to the conductor size selection in planning radial distribution systems for productivity improvement using ICA approach", International Journal On Technical And Physical Problems Of Engineering (IJTPE), ISSUE 15, VOL. 5, NO. 2, PP. 1-5.
- [19] GJ Anders, M Vainberg, DJ Horrocks, SM Foty, J Motlis, J Jarnicki (1993) Parameters affecting economic selection of cable sizes," IEEE Trans. Power Del., 8(4):1661-1667.
- [20] S Mandal, A Pahwa (2002) Optimal selection of conductors for distribution feeders," IEEE Trans. Power Syst., 17(1):192-197.