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Research Paper

Analysis and Reconductoring of Overhead Conductors with Considering Aging for Radial Distribution Systems Using Imperialist Competitive Algorithm

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Abstract: *In medium voltage electrical distribution networks, prevent 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. 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. Hence proper selection of conductors in the distribution system is important as it determines the current density and the resistance of the line. Evaluation aging conductors for losses and costs imposed in addition to the careful planning of technical and economic networks can be identified in the network design. This paper examines the use of different evolutionary algorithms, imperialist competitive algorithm (ICA) to optimal branch conductor Selection and Reconstruction In view of the aging conductors in planning radial distribution systems with the objective to minimize the overall cost of annual energy losses and depreciation on the cost of conductors in order to improve productivity. Simulations are carried out on actual power network of Kerman Province, Iran using ICA approaches in order to show the accuracy as well as the efficiency of the proposed solution technique.*

Keywords: Distribution system optimization, Imperialist competitive algorithm, radial distribution systems, Backward-Forward sweep, Loss Reduction, Aging conductors.

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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, 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]. 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 model, the behavior of the power type load is assumed to be constant. Several studies have used evaluative techniques to solve the CSS problem [8]–[10]. In [11] the optimal CSS placement is solved using a genetic algorithm. In this paper, optimal type of conductor selection is proposed for planning radial distribution systems using different evolutionary algorithms, imperialist competitive algorithm (ICA). The objective is minimizing the overall cost of annual energy losses and depreciation on the cost of conductors in order to improve productivity with considering the maximum current carrying capacity and acceptable voltage levels. Moreover, we utilize the Backward-Forward sweep method which is simple, flexible, reliable, and didn't need Jacobean matrix and its inverse and have high convergence speed.

2. Optimal Conductor Size Selection

The conductor size selection problem involves determining the optimal conductor configuration for a radial distribution system, using a set of types of conductors. Each type of conductor has the following characteristics: 1) resistance per length, 2) reactance per length, 3) maximum current capacity, 4) cross-sectional area and 5) building cost per length.

3. Power Flow Analysis Method

The methods proposed for solving distribution power flow analysis can be classified into three categories: Direct methods, Backward-Forward sweep methods and Newton Raphson (NR) methods. The Backward-Forward Sweep method 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 Kirchhoff'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].

4. Aging Conductors Analysis

Conductors 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 Post, with 18.74 Km of the Kerman area Inclusive conductors such as Hayna, Doug and Mink. Also in this paper with coordination of the Kerman province north of electricity distribution companies Examples of the conductors such Hayna, dog and mink suffering of life measures were collected at 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

Table 1: Analysis Conductors properties

A [mm^2]	R [Ω/km]	Year
70	0.4545	new
70	0.4580	1
70	0.4760	38
120	0.2712	new
120	0.3320	42
126	0.1576	new
126	0.2130	24
126	0.2430	26

5. 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 *c* in branch *i* is written as

$$Min\ f(i,c)= w1*CE(i, c)+ w2*DCI\ (i, c)+w3*C_{ENS}$$

Subject to

$$Vmin \leq |Vi| \leq Vmax \qquad i=1, 2,3,....,n$$

$$|I\ j| \leq Imax \qquad j= 1,2,3,....,n-1$$

Where CE (i,c) is the Cost of Energy Losses and C_{ENS} is the Cost of … reliability and DCI (i,c) is Depreciation on Capital Investment of *c* conductor type of *i-th* branch, 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,

$$CE(i,c)=P\ L(i, c)*\ \{KP+ KE *\delta*T\}$$

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). Depreciation on capital investment is given as

$$DCI(i,c) = \gamma * A(c) * \{C_c + L_i\}$$

Where γ 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).

$$C_{ENS} = \frac{h}{8760} \times \sum_i U_i \times PL_i \times Cost\_Shed_i$$

Where C_{ENS} the cost of energy not supplied ($); U_t : i mean outage times a year (hour/year); $Cost\_Shed_i$: Cost of outage time ($/Kwh). Average time to confirm any of the loads of the network is obtained from the following equation

$$U_i = \sum_j \lambda_{ij} \times r_j$$

Where λ_{ij}: Number of failures per year for equipment failures that results in lost time, i is the j. r_j: The average time required to fix your equipment after each fault j (hour).

6. Imperialist Competitive Algorithm

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 flow chart of proposed ICA is depicted in Fig. 1.

7. Results and Discussion

Simulations are carried out on actual power network of Kerman Province, Iran 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. Length of all branches is considered to be equal to 60m. The properties of the new conductors used in the analysis of this system are given in Table 2. The initial data for load flow solution based on the Backward-Forward sweep are selected as: V_b=20 Kv, S_b=100 Mva. The other parameters used in computation process are: KP = 1.04 ($/kW); KE = 0.012 ($/kWh).

Table 2: 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

The parameters used in ICA 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. Convergence values for ICA fitness functions are illustrated in Fig. 3.

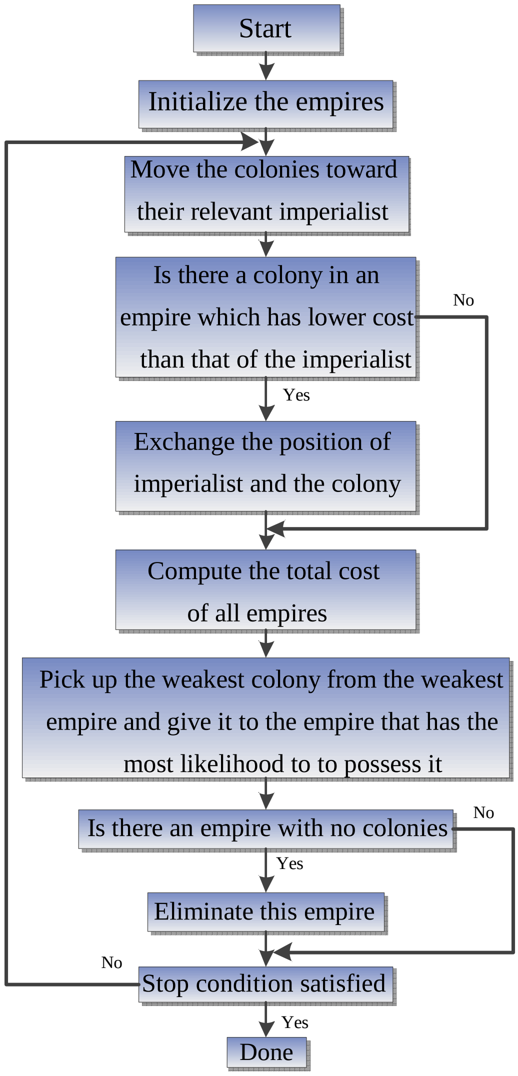

Fig 1: Flowchart of the proposed ICA algorithm

Fig 2: Single line diagram for a actual power network of Kerman Province, Iran

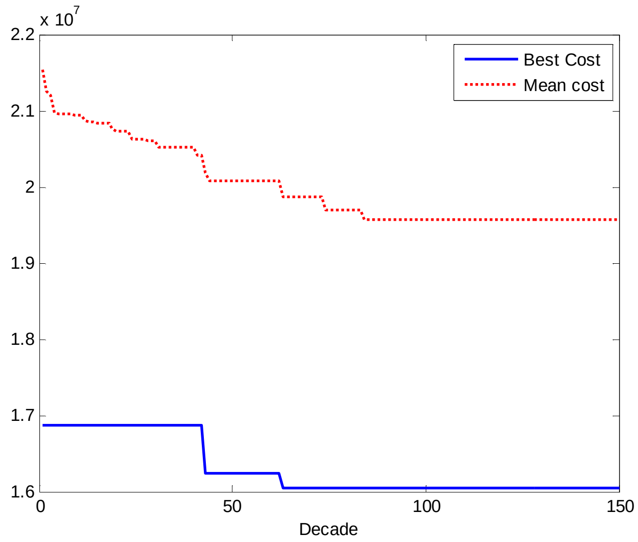

Fig 3: Convergence values for ICA fitness functions

The voltage profile and Power loss in the system after ICA implementation is compared with Conventional conductor design and depicted in Fig. 4 and Fig. 5. It can be seen that the voltage profile achieved by ICA optimization algorithms are almost the same while having better improvement in compare with Conventional method. Moreover, a decrease in peak power loss based on peak power loss profiles is illustrated. The total power loss is shown in Fig. 6 and the costs based on conductor selection are compared in Table 3. The real power loss reductions are 606.7364 kW, which is approximately 5.6% in compare with the Conventional design for ICA respectively. Proceedings in a similar manner, the total cost reduction (sum of annual cost of power loss and depreciation on capital investment cost) are obtained 30% for ICA respectively.

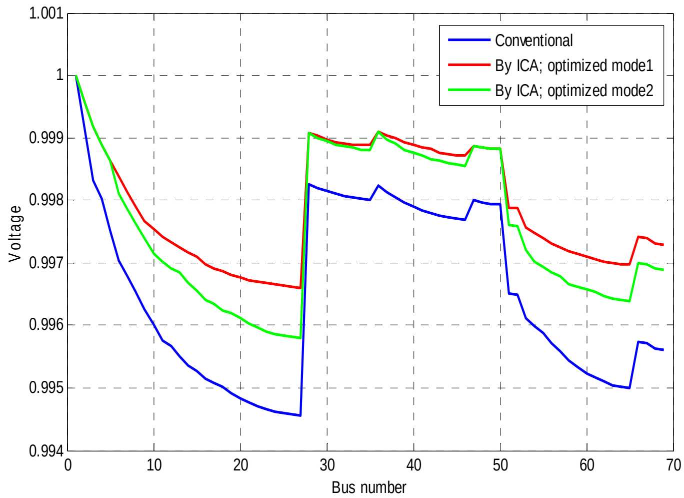

Fig 5: Voltage profiles of model system

Mode1: optimization using ICA with consideration of aging conductors
Mode2: optimization using ICA with consideration of new conductors

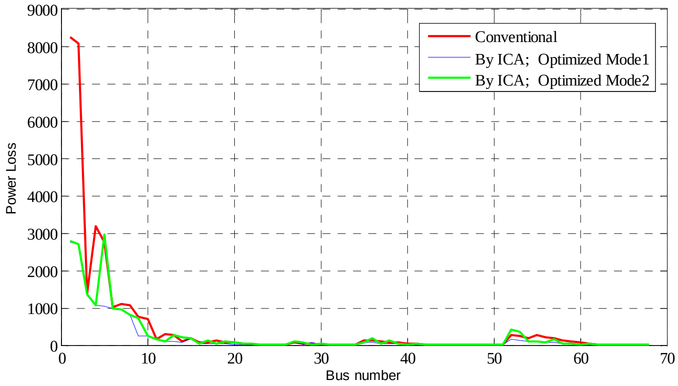

Fig 5: Peak power loss profiles in each branch

Mode1: optimization using ICA with consideration of aging conductors
Mode2: optimization using ICA with consideration of new conductors

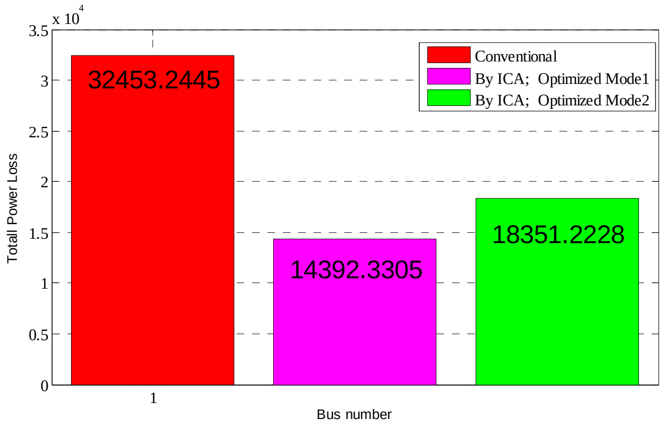

Fig 6: Total power loss for different conductor selections method

Mode1: optimization using ICA with consideration of aging conductors
Mode2: optimization using ICA with consideration of new conductors

Table 3: Obtained Loss results

Method	Total Loss [W]	Total Cost [$]
Conventional	32453.24452	15852672
ICA with consideration of new conductors	14392.33046	47420208
ICA with consideration of new & aging conductors	18351.2228	50813136

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