A Practical Approach to Optimal Selection of Conductors Planning Radial Distribution Systems for Productivity Improvement

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Abstract

Selecting the optimum type and size of conductors for planning and optimization of distribution networks is an essential part of the design process. In this paper, a new and efficient algorithm to the optimal selection of conductors of feeder sections of radial distribution networks is proposed. In optimization procedure, cost of conducting material, cost of energy losses, bus voltage profile and current carrying capacity of conductors are considered. 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.
This paper presents optimal branch conductor selection of radial distribution systems using intelligent methods for based of CSA and compared with algorithm PSO to minimize the overall cost of annual energy losses and unavailability of conductors in order to improve productivity. Simulations are carried out on 69-bus & 30-bus radial distribution networks optimization methods. Results obtained with the proposed approaches are compared.

Keywords: Optimal Conductor Selection, Colonial Selection Algorithm, radial distribution systems, back/forward sweep, Loss Reduction, productivity improvement.

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I. 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 (CSA). The objective is minimizing the overall cost of annual energy losses and depreciation on the cost of conductors and reliability 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 Jacobian matrix and its inverse and have high convergence speed.

II. LOAD FLOW METHOD

The methods proposed for solving distribution power flow analysis can be classified into three categories: Direct methods, Backward-Forward sweep methods and

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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 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].

III. EVOLUTIONARY ALGORITHMS IMPLEMENTATION

In artificial intelligence, an Evolutionary Algorithm (EA) is a subset of Evolutionary Computation that involves combinatorial optimization problems. Optimal branch conductor selection of radial distribution systems using evolutionary methods of Imperialist Competitive Algorithm (CSA) is investigated.

IV. OBJECTIVE FUNCTION

The objective of optimal conductor selection is select conductor size from the available 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.

$$\mathrm{Min.imize}\ f(i,c) = CE\_CC(i,c) \quad (2)$$

subject to

$$|V(m,c)|\ \ V_{min}\ \mathrm{for}\ m\ \ 2,3,\ldots.,k \quad (3)$$

$$|I\ (i,c)|\ \ I_{max}(c)\mathrm{for}\ i\ \ 1,2,3,\ldots.,b \quad (4)$$

where f is sum of depreciation on capital investment and cost of energy losses of CE is the cost of Energy Losses DCI is depreciation on capital investment; i is branch in system; c is the type of conductor used in the branch; k is total number of buses in the network; b is total number of branches.

The annual cost of loss and unavailability in branch i with conductor type k is,

$$CE\_CC_{(i,c)} = \mathrm{Peak\,Loss}(i,c)\{KP + KE\ *\ LSF *\ T\} + UNA(i,c)\ \ (5)$$

where Kp is Annual demand cost due to power loss (Toman/kW); Ke is Annual cost due to energy loss(Toman/kWh); LSF is Loss factor; Peak loss(i,c) is Real power loss of branch; i under peak load conditions with conductor type c; T is the time period in hours (8760 hours). Unavailability (UNA) index for reliability is given as

$$UNA(i,c) = \mathrm{Pload(node)} * \{r(\mathrm{branch}) * \lambda(\mathrm{branch})\}\ (6)$$

Loss factor is defined as ratio of energy loss in the system during a given time period to the energy loss that could result if the system peak loss had persisted throughout that period. In British experience, loss factor isexpressed in terms of the load factor (Lf) as

$$LSF\ =\ 0.84\ Lf\ 2 +\ 0.16Lf\ \ (7)$$

The evaluation of fitness function is a procedure to determine the fitness of each string in the population. Since the algorithm proceeds in the direction of evolving best-fit strings and the fitness value is the only information available to the Colonial Selection Algorithm the performance of the algorithm is highly sensitive to the fitness values. The fitness function F, which has been chosen in this problem, is

$$F = \frac{1}{1 +\ f(i,c)}\ \ (8)$$

V. COLONIAL SELECTION ALGORITHMS

Accordingly explain various steps involved in the implementation of CSA for optimal conductor selection problem are:

1: In put parameters of system, and specify the lower and upper boundaries of each variable.

2: Initialize Discrete the particles of the population. These initial particles must be feasible candidate solution that satisfies the practical operation constraints.

3: To each particles of the population, employ the Backward Forward method to calculate power flow and the transmission loss.

4: Calculate the evaluation value of each colonial, in the population using the evaluation function.

5: Compare each particle's evaluation value with its pBest.

6: Update the inertia weight w given by

$$W = Wmax - \frac{(Wmax - Wmin)}{Itermax} \quad (9)$$

7: Modify the velocity v of each particle according to the mentioned equation.

$$V(k,j,i+1) = w * V(k,j,i)$$
$$+ C1 * rand * \left(pbestx\,(j,k) - x(k,j,i)\right) +$$
$$+ C2 * rand * \left(gbestx\,(k) - x(k,j,i)\right) \quad (10)$$

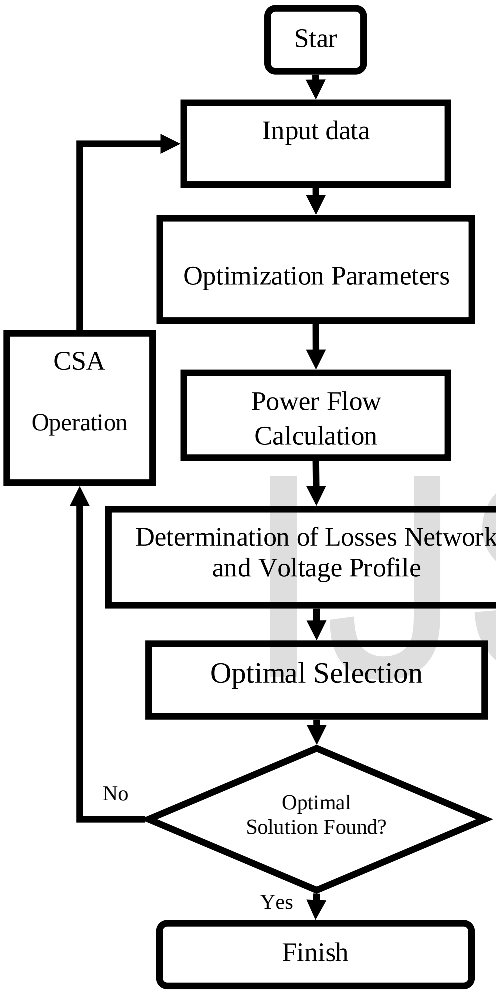

Fig 1: Flowchart of the proposed CSA algorithm

VI. TESTS AND RESULTS

Simulations are carried out on 69-bus radial distribution network using CSA 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 and 3. 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 1.The initial data for load flow solution based on the Backward-Forward sweep are selected as: . The other parameters used in computation process are: KP = 1.04 ($/kW); KE = 0.012 ($/kWh).

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

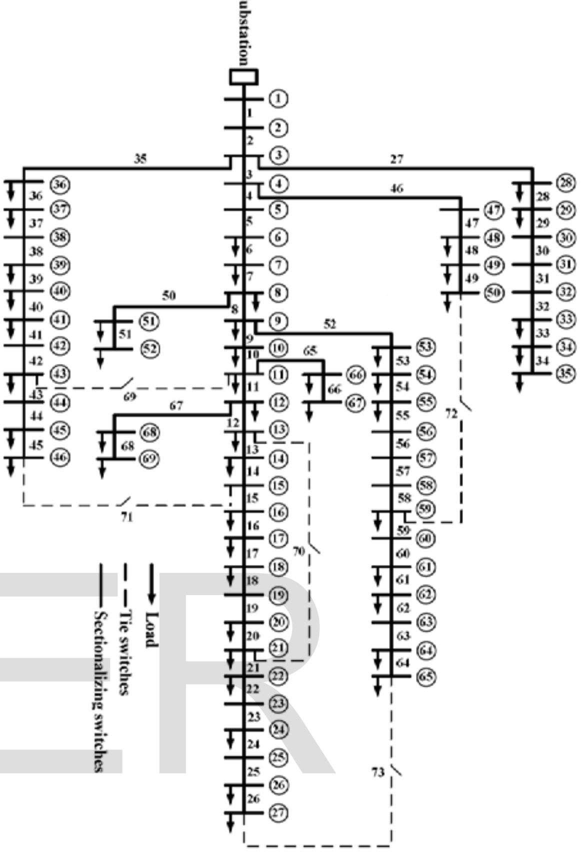

Fig 2: Single line diagram for a 69-bus radial distribution system

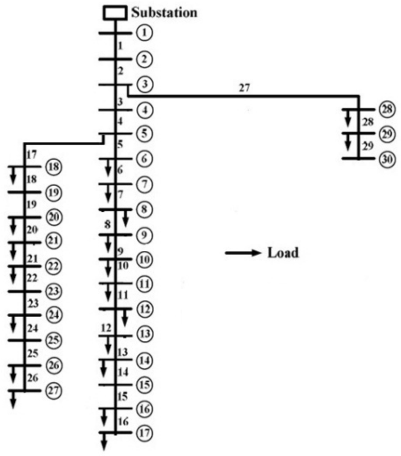

Fig 3: Single line diagram for a 30-bus radial distribution system

The parameters used in CSA 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 (2 and 3). The Voltage profile and Power loss and Type Conductor branch in the system CSA compared Conventional and PSO implementation is compared with Conventional conductor design and depicted Respectively in fig (3 and 4) and fig (5 - 6) .

Table 2 : Conductor selection results.

Conductor Design Method	Type (No.)	Branch Number
PSO Based	Hyena (1)	From 1 to 26
	Dog (2)	Rest of 68 branches
CSA Based	Hyena (1)	20,21,28,38,43
	Mink (3)	Rest of 68 branches
Conventional	Hyena (1)	-
	Mink (3)	All branches

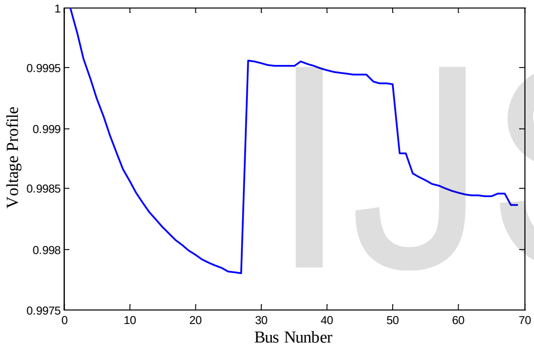

Fig 3: Voltage profiles of 69-bus system

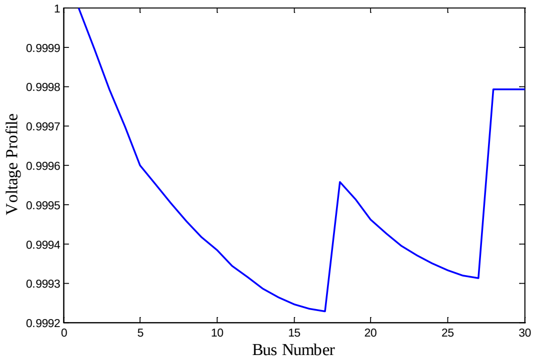

Fig 3: Voltage profiles of 30-bus system

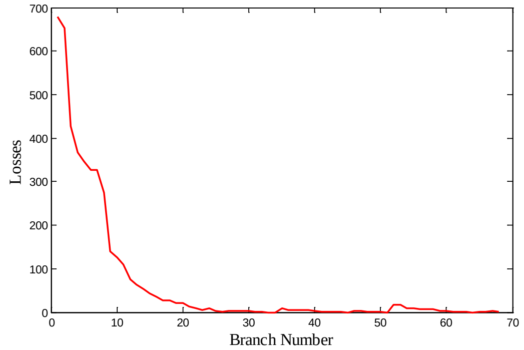

Fig 5: Peak power loss profiles in each branch

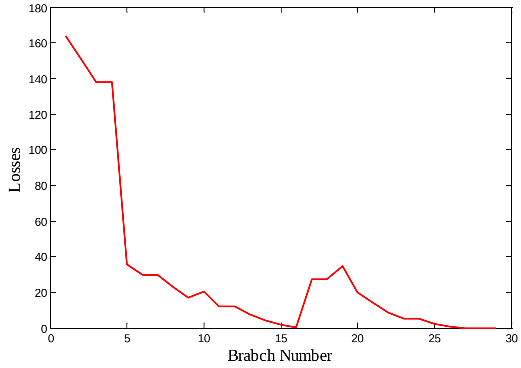

Fig 6: Peak power loss profiles in each branch

Table 2: Obtained Loss results

Algorithm	Total	Annual
	Cost Loss [million Reial]	Cost [million Reial]
with out	23125.42824	21136896
with PSO	10992.23002	51846696
with CSA	10148.28919	51838776

Table 3: Obtained Loss results

Algorithm	Total	Annual
	Cost Loss [million Reial]	Cost [million Reial]
with out	12325.42824	18736896
with PSO	10192.23002	36846696
with CSA	9148.28919	36838776

VII. CONCLUSION

This study has presented a novel approach to solve the optimal conductor selection problem in a radial distribution network. The objectives considered attempt to minimize of capital investment and power loss, subject to voltage drop and current carrying capacity constraints. Optimal set selection of conductors for designing a distribution system is a challenging problem. In this paper, an optimal conductor selection in radial distribution systems is proposed with goal of productivity improvement using CSA compared PSO approaches. In these approaches, optimal selection of branch conductor is done by minimizing the sum of cost of energy losses and depreciation cost of feeder conductor. The proposed algorithms were tested on 69-bus and 30-bus system and results obtained are encouraging.

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