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Optimal conductor selection in radial distribution using bacterial foraging algorithm and comparison with ICA method

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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 this paper, we optimize an objective function to reduce the sum of capital cost and power loss cost and voltage deviation of radial distribution network of power simultaneously. This results in saving substantial amount of energy. To reduce our objective function, we find optimized type of conductor by taking use of Bacteria foraging algorithm (BFA) method and comparison with Imperialism Competitive Algorithm (ICA) Method. This computational method, iteratively improve a potential type of conductor with respect to a given measure of quality to reach to the optimized type of conductor. The back/forward sweep method is applied for load flow solution of proposed radial distribution system. The power loss reduction and voltage profile improvement has been successfully achieved which demonstrate the effectiveness of the proposed methods.

Key words: *Conductor Size; Imperialism competitive algorithm (ICA); Bacteria foraging algorithm (BFA); Radial distribution networks; Back/forward sweep; Voltage profile; Loss reduction.*

1. Introduction

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. In addition, in most articles there is not any special 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 (Mozaffari Legha, 2011). 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) (Sharafi et al., 2011; Sedighizadeh et al., 2011). Dynamic programming approach was utilized to solve the CSS problem in (Mozaffari et al., 2013). They presents models to represent feeder cost, energy loss and voltage regulation as a function of a conductor cross-section. In (Sedighizadeh et al., 2011), the conductor size selection performed with consideration of financial and engineering criteria in the feeder. In (Mozaffari and Gadari1, 2013) and (Mozaffari, 2011) the CSS problem is solve using heuristic methods. Reference (Mozaffari and Gadari1, 2013) 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 (Mozaffari, 2011) 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 (Rider et al., 2012), while other approximates the load as a constant current model (Mozaffari et al., 2013). In (Rider et al., 2012), a mixed integer linear model for the problem of conductor selection size in radial distribution systems is presented. The imperialism competitive algorithm (ICA) method

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and comparison with ICA Method (Sharafi et al., 2011). 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 (Mendoza et al., 2006; Rao, 2010). In the optimal CSS placement is solved using a genetic algorithm (Vahid et al., 2009).

In this paper, optimal type of conductor selection is proposed for planning radial distribution systems using Bacteria foraging algorithm (BFA) method and comparison with Imperialism Competitive Algorithm (ICA) Method. 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.

2. Power flow analysis method

The methods proposed for solving distribution power flow analysis can be classified into two categories: Newton-Raphson (NR) method and Backward-Forward sweep 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 (Medina et al., 2003).

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 (Medina et al., 2003).The Backward-Forward sweep Flowchart of the method depicted in Fig.1(Medina et al., 2003).

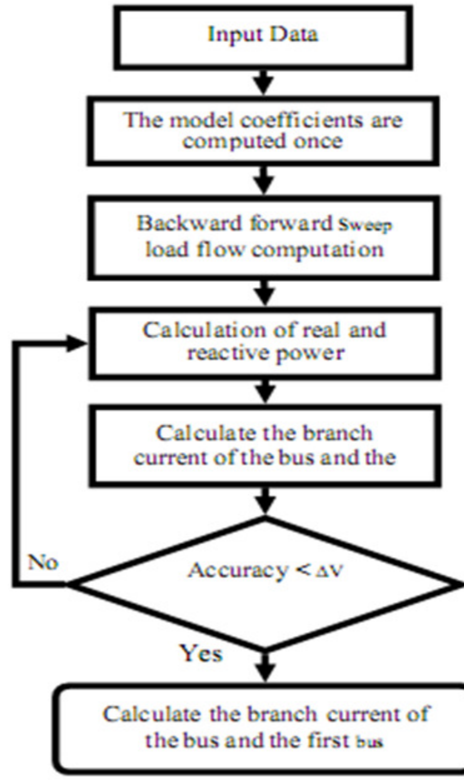

Fig.1: Flowchart of the Backward-Forward sweep method

3. 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 am written as:

$$Min\ f(i,j)= w1*CE(i,j)+ w2*DCI\ (i,j) \quad (1)$$

Subject to

$$Vmin \leq |Vi| \leq Vmax \quad i=1,2,3,\ldots,n \quad (2)$$

$$|I\ l| \leq Imax \quad l= 1,2,3,\ldots,n-1 \quad (3)$$

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), Vmin for any bus= 0.95 and Vmax for any bus= 1.05; IMAX for any line is According to table1. The annual cost of loss in branch i with conductor type k is,

$$CE(i,c)=P\,L\,(i,j)*\{KP+ KE*\beta*T\} \quad (4)$$

In Equation (4) Kp is annual demand cost due to Power Loss (\$/kW), KE 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

$$DCI(i,j) = \alpha * A(j) * \{C_j + L_i\} \qquad (5)$$

Where α is Interest and depreciation factor, Cj is cost of type conductor ($/km), A (j) is cross-sectional area of j type conductor and Li is length of branch i (km). The flow chart of proposed method is depicted in Fig.2.

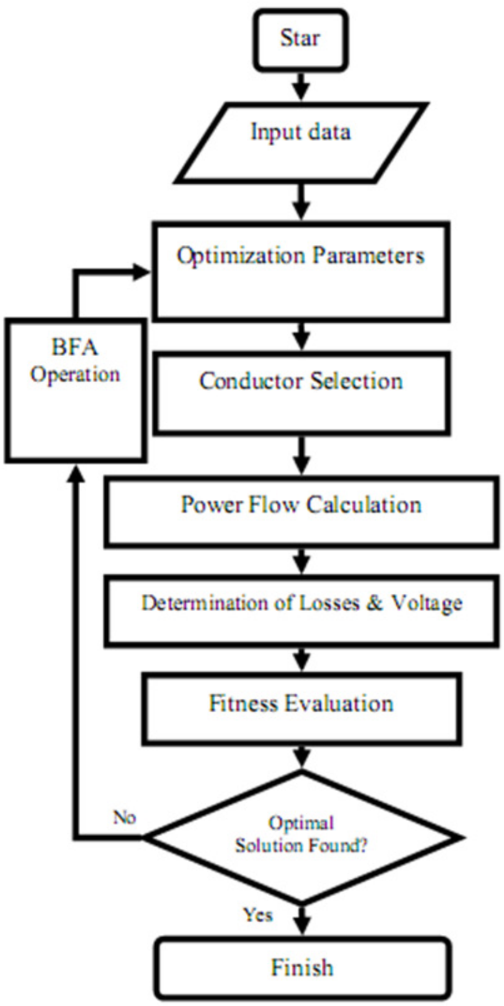

Fig.2: Flowchart of the proposed BFA algorithm

4. Bacterial foraging algorithms

Natural selection tends to eliminate animals with poor foraging strategies and favor the propagation of genes of those animals that have successful foraging strategies (Atashpaz and Lucas, 2007). 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: chemotaxis, swarming, reproduction, elimination and dispersal The chemotaxis 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 (Tripathy and Mishra, 2007; Mishra et al., 2007). An E. coli bacterium alternates between running and tumbling. At down, the E. coli bacterium is is depicted in Fig.3. The flow chart of proposed method is depicted in Fig.4.

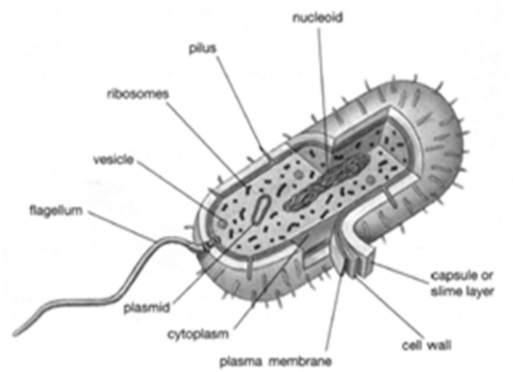

Fig.3: An E. coli Bacterium

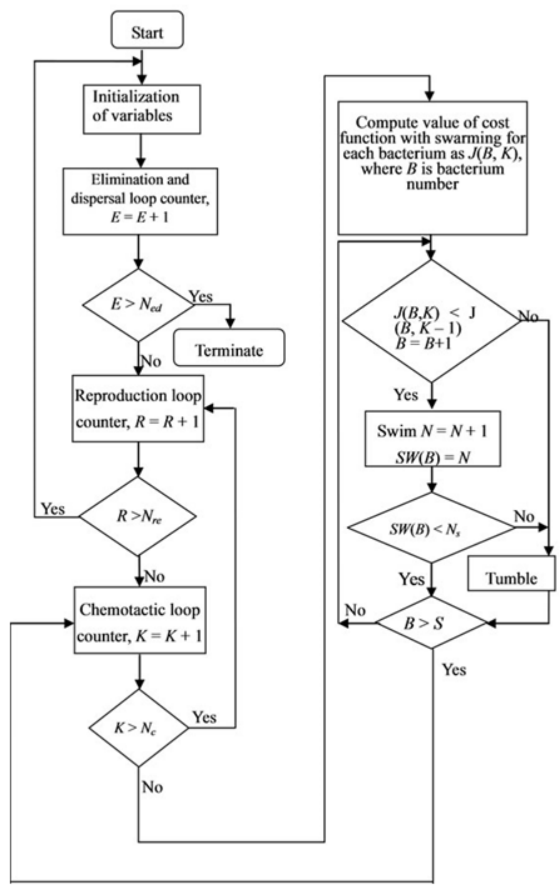

Fig.4: Flowchart of the proposed BFA algorithm

5. Tests and results

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 mm^2), Doug (A=120 mm^2) and Mink (A=70 mm^2). The single line diagram for proposed radial distribution systems is shown in Figure 5. 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: V_{base}= 20kV, and S_{base}= 100kVA Vmin for any bus= 0.95 and Vmax for any bus= 1.05, 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 other parameters used in computation process are: KP = 1.04 ($/kW); KE = 0.012 ($/kWh) (Sharafi et al., 2011; Sedighizadeh et al., 2011; Mozaffari, 2011). The conductor properties is in Table 1 also the conductor type is in Table 2.

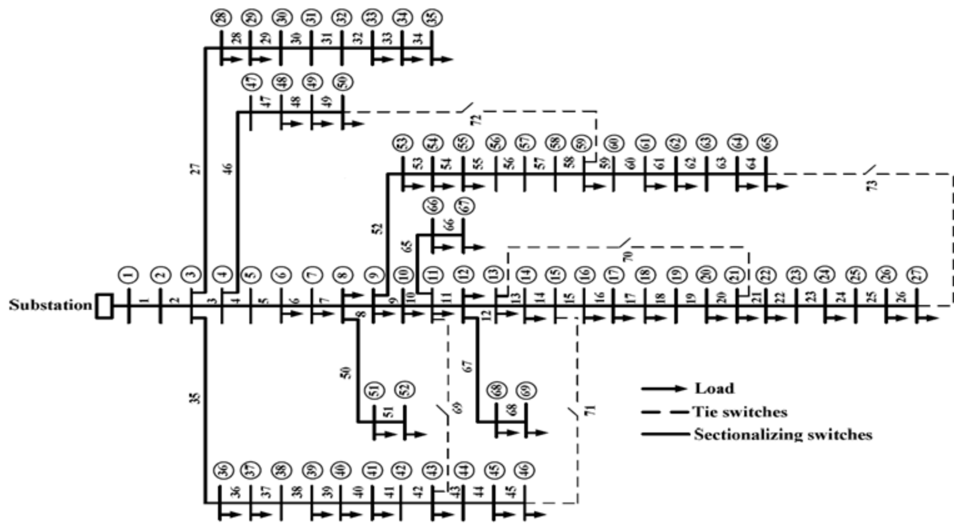

Fig.5: Single line diagram for a 69-bus radial distribution system

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	4075
Dog	0.2712	0.2464	440	120	3500
Mink	0.4545	0.2664	315	70	2125
Fox	0.7822	0.2835	216	42.8	1765

Table 2: 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 results of conductor selection with BFA method is compared with ICA method and Conventional are shown in Table 3. The voltage profile in the system with BFA method is compared with ICA method and Conventional are shown in Fig.6. Also the power loss each branch in the system with BFA method is compared with ICA method and Conventional are shown in Figure 7. The real power loss reductions are 1.045 MW with BFA Method and real power loss reductions are 0.98 MW with ICA Method; which BFA method is approximately over the 42.5% in compare with the Conventional design. The total power loss of 69-bus system is shown in Fig.8 and Table 4.

Table 3: Conductor selection results

Conductor Design Method	Type	Branch Number
Conventional	Hyena	From 1 to 26
	Dog	Rest of 68 branches
	Mink	---
ICA Based	Hyena	From 1 to 5
	Dog	From 1 to 5
	Dog	23,24,25,26
BFA Based	Hyena	From 1 to 14
	Dog	15,16, From 21 to 24, From 40 to 44, From 61 to 66
	Mink	Rest of 30 branches

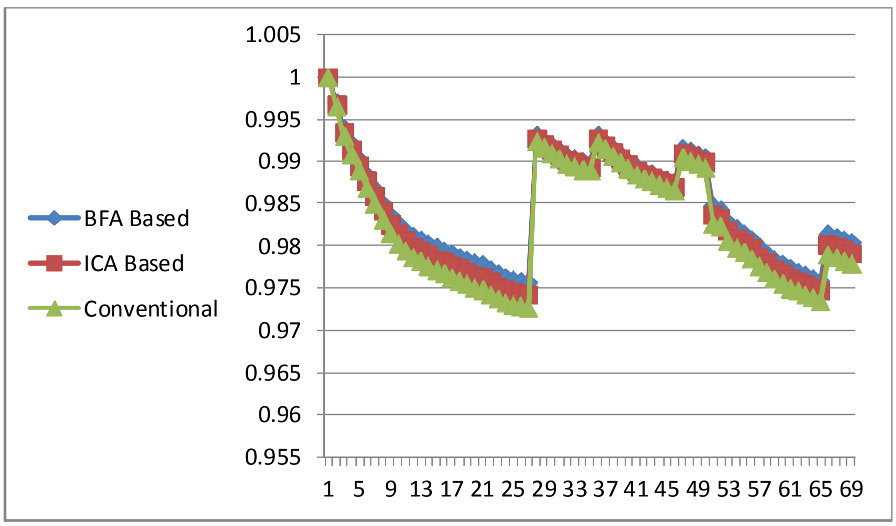

Fig.6: Voltage profiles of 69-bus system

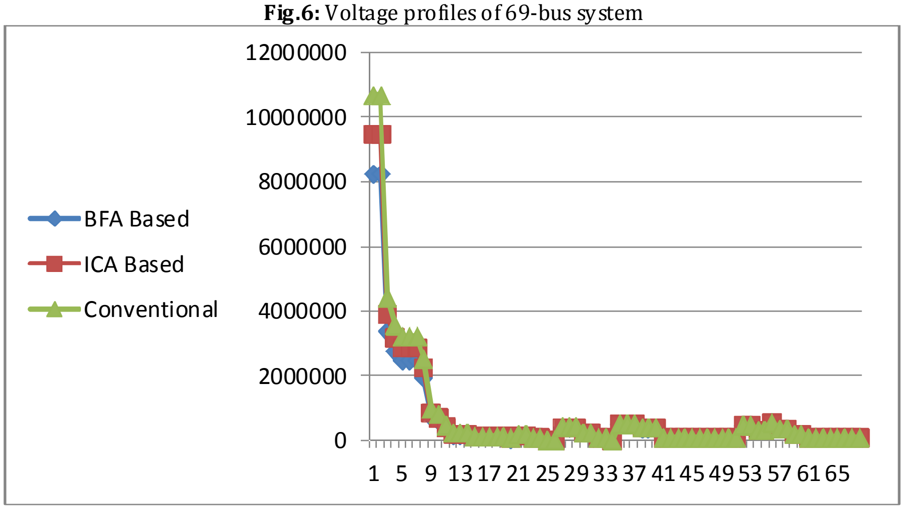

Fig.7: Peak power loss profiles in each branch

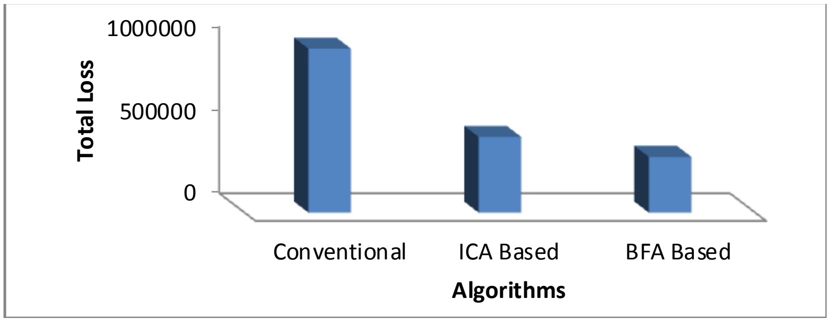

Fig.8: The total power loss of 69-bus system

Table 4: Obtained Loss results of 69-bus system

Algorithm	Total Loss
Conventional	985555.65
ICA Based	455225.65
BFA Based	335265.65

6. 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 and reliability 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 (BFA) in comparison with a conventional and ICA method is investigated using a case studt of 69-bus radial distribution 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 BFA for improving plant productivity and economy.

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