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A novel approach based on crow search algorithm for optimal selection of conductor size in radial distribution networks

Almoataz Y. Abdelaziz [a], Ahmed Fathy [b,*]

[a] Electric Power & Machine Dept., Faculty of Engineering, Ain-shams University, Cairo, Egypt
[b] Electric Power & Machine Dept., Faculty of Engineering, Zagazig University, Zagazig, Egypt

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ABSTRACT

The selection process of conductor size in radial distribution network is very essential issue to improve the performance of the network. The true conductor size selection leads to less power loss, achieve improvement of the bus voltage profile and obtain reduction in the annual operating cost of the system. This paper proposes a novel approach based on crow search algorithm (CSA) for optimal selection of the conductors in a radial distribution network. The CSA is a recent meta-heuristic algorithm which is based on the intelligent behavior of crows. The objective function presented in our work is the sum of conductor capital cost and the conductor energy loss cost. The proposed constraints are bus voltage limits and the current capacity of the conductor. The independent variables are the type and the size of conductor such that minimizing the proposed objective function. The proposed approach is applied on two different network topologies, the first one is 16-bus system and the second is large scale system of 85-bus system. A sensitivity analysis of the CSA controlling parameters are also studied for 16-bus system. The obtained results via CSA are compared to previous works' results; the CSA results encourage the usage of the proposed approach in optimal selecting the conductor type and size in the distribution network.

1. Introduction

The challenges faced the distribution networks have been raised in the last decades as the main requirement of operating the radial network is its reliability. It is known that the number of resources in such networks is limited and the disconnection of any feeder will prevent supplying the load. Therefore, it is important to select proper types of conductors able to carrying the required energy to load.

Many researchers studied the optimal selection of the conductors in radial networks. A review study of optimal selecting the conductor size in radial network approaches has been presented in [1]. These literature methodologies can be classified into two main categories; the first one is conventional approaches based on analytical analysis [2–4] and the second is based on meta-heuristics as genetic algorithm [2,5–7], evolutionary strategies [8,9], modified differential evolution [10], imperialist competitive algorithm [11], bacterial foraging algorithm [12], particle swarm optimization (PSO) [13], discrete particle swarm optimization [14], partial enumeration technique [15], harmony search algorithm with a differential operator [16].

Thenepalle [2] introduced two comparative approaches of optimal selection for conductors in radial network such that minimizing the power losses, maximizing the cost saving and maintaining the bus voltages in their corresponding limits. The first approach is analytical one based on performing load flow study while the second is based on genetic algorithm. Sivanagaraju et al. [3] presented an analytical approach based on radial network load flow to select the suitable conductor size to maximize saving in conductor capital and energy loss costs. Satyanarayana et al. [4] presents a model of overloading to improve the loading of radial feeder based on the optimal selection of the conductor. Legha et al. [5] used GA to select the conductor size to minimize the system overall annual cost, a backward-forward sweep method has been used to perform the load flow study of radial network. In [6] two actions are taken via GA; the capacitor optimal placement and the optimal selection of conductors in radial network to reduce the system losses and enhance the voltage profile. Sharma et al. [7] presented an approach based on GA to minimize the network losses and maximize the saving cost via selecting the networks' conductors optimally. Mendoza et al. [8] presented an evolutionary strategy (ES) to solve the problem of selecting the network feeders while Ranjan

* Corresponding author.
E-mail address: afali@zu.edu.eg (A. Fathy).
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et al. [9] used evolutionary programming (EP) algorithm to solve the problem. Kalesar et al. [10] presented a modified differential evolution (MDE) to solve the problem of selecting the conductors in radial network taken the conductor capital cost, power loss and energy loss cost as objective function. Legha et al. [11–13] introduced the imperialist competitive algorithm (ICA), bacterial foraging algorithm (BFA) and particle swarm optimization (PSO) to solve the optimal selection of network feeders. Sivanagaraju et al. [14] considered the discrete particle swarm optimization (DPSO) is suitable for selecting the conductors in radial network. Kaur et al. [15] concerned with the power cost and peal load diversity during a certain period in determining the optimal conductor type in a distribution network using partial enumeration technique. Rao et al. [16] combined the harmony search algorithm with a differential operator for optimal selecting the network conductors to minimize the conductor investment and energy loss costs taking the bus voltages and conductors' maximum current capacity as constraints.

In this work; a novel approach based on a recent meta-heuristic algorithm, crow search algorithm (CSA), is proposed to solve the problem of optimal selection of the distribution network conductors' types. A constrained objective function combined the conductor capital and the conductor energy loss costs are presented. The bus voltage limits and the max current carrying capacity of conductor are considered as constraints. The proposed CSA is applied on two different network topologies, 16-bus system and 85-bus system. A sensitivity analysis of the CSA controlling parameters, maximum iteration, flight length and awareness probability, are studied for 16-bus system and the best set of these parameters are taken in analyzing 85-bus system. The obtained results via the CSA are compared to others in previous works; the results ensure the superiority of the proposed algorithm in solving the problem of optimal selection of the radial network conductor type.

2. Optimization problem formulation

In this section the objective function and the proposed constraints are presented.

A. Objective function

The main object of this work is to select a suitable conductor in radial distribution network that minimizes the sum of the conductor capital cost and the conductor energy loss cost with keeping acceptable bus voltage profile and achieving acceptable power flow in the network branches. Assuming that the conductor to be selected is between two buses m and n as shown in Fig. 1, the current I_{mn} is flowing from bus m to bus n to supply the load connected to bus n. The conductor power loss can be calculated as follows:

$$P^{loss} = |I_{mn}|^2 R_{mn} = \frac{(P_n^2 + Q_n^2)}{|V_m|^2} R_{mn} \tag{1}$$

The total annual cost of the energy loss can be written as follows [17]:

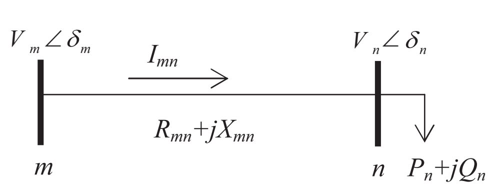

Fig. 1. Electrical equivalent of a conductor between two buses.

$$C_t^{E_{loss}} = \sum_{i=1}^{n_b} [P^{loss}(i) \times (K_P + K_E \times T \times LSF)] \tag{2}$$

where $P^{loss}(i)$ is the power loss of branch i, K_P is the annual cost of the losses (Rs/kW), K_E is the cost of energy loss (Rs/kWh), T is the period in hours (8760 h.), LSF is the loss factor and n_b is the number of branches.

The annual capital investment cost for a branch i of type j is given as follows:

$$C^c(i,j) = \alpha \times A(j) \times C \times L(i) \tag{3}$$

where α is the carrying charge rate, $A(j)$ is the cross section area of branch of type j (mm^2), C is the cost of the line (Rs/mm^2.km) and $L(i)$ is the length of conductor i (km).

Finally, one can write the objective function as follows:

$$F = C_t^{E_{loss}} + C_t^c = \sum_{i=1}^{n_b} \sum_{j=1}^{n_c} [P^{loss}(i) \times (K_P + K_E \times T \times LSF) + \alpha \times A(j) \times C \times L(i)] \tag{4}$$

where C_t^c is the total capital investment cost of all branches and n_c is the number of allowable conductors' types.

B. Constraints

The proposed constraints can be described as follows:

- Bus voltage constraints

$$V_{\min(j)} \leqslant |V(j)| \prec V_{\max(j)} \quad \forall j \in n_{bus} \tag{5}$$

- Maximum current carrying capacity

$$|I(i,c)| \leqslant I_{\max(c)} \quad \forall i \in n_b \tag{6}$$

where $V_{min(j)}$ and $V_{max(j)}$ is the minimum and maximum voltage at bus j, n_{bus} is the number of buses, I(i, c) is the flow in conductor i of type c and $I_{max(c)}$ is the maximum allowable current flows in conductor c.

3. Crow search algorithm

At recent days, Askarzadeh [18] proposed a novel metaheuristics optimization algorithm based on the social behavior of the crow and named Crow Search Algorithm (CSA). The idea of CSA is motivated from the storing process of the excess food in hiding places then restoring it in the necessary time. It is known that the crow is very intelligent bird that observes the others hide their food and steal it once they leave. After committing the theft, it hides to avoid being a victim in the future. It is assumed that a flock of N crows, the crow number i has position at iteration k is x_i^k. The hiding place of the food followed by crow i is memorized. Crow moves in the search plane and tries to find the best food source which is defined as m_i^k. The searching approach in CSA has two probable scenarios; the first one is that the owner crow j of food source m_j^k doesn't know the thief crow i follows it therefore the thief crow reaches to the hide place of owner crow. The updating process of the crow thief position is done by

$$x_i^{k+1} = x_i^k + r_i \times fl_i^k \times (m_j^k - x_i^k) \tag{7}$$

where r_i is a random number in range [0,1], fl_i^k is the flight length of crow i at iteration k.

The second probable scenario is that the owner crow j know that the thief crow i follows it therefore, the owner crow will deceive crow i by going to any another position of search space. The position of crow i is updated by a random position.

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