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A Novel Approach for Reactive Source Sizing and Placement in Distribution Networks

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ABSTRACT

The integration of capacitor banks in distribution network is a challenging issue. These electric resources are used as a reactive power resource for decreasing the active losses and also improving the voltage profile. In this paper a heuristic method named imperialist competition algorithm is proposed for fixed capacitor allocation in a distribution network. The objective function to be minimized is defined as the total cost of active losses and investment costs of capacitor units. The method is applied on a test distribution network and the results are presented and discussed and compared to other methods.

KEY WORDS: Capacitor bank, Imperialist competition algorithm, active loss, optimization.

1. INTRODUCTION

In deregulated power systems, the distribution network operators (DNOs) are responsible for maintaining the secure and reliable operation of distribution network. This can be done by distribution network reconfiguration, feeder reinforcement, integration of distributed generations and capacitor bank investment. The integration of capacitor banks will change the reactive flow of feeders and this would affect the voltage profile and also the active losses of the network. Different approaches have been presented for optimal capacitor allocation in power distribution networks.

In [1], a bacteria foraging algorithm was proposed to select the installation node using the fuzzy reasoning. The objective function is defined as the sum of loss cost and capacitor installation. In [2], an optimization algorithm for simultaneous improvement of power quality (PQ), optimal placement and sizing of fix capacitor banks in radial distribution networks in the presence of voltage and current harmonics was proposed. In [3], a Plant Growth Simulation Algorithm (PGSA) for capacitor placement in radial distribution systems was introduced in order to determine the optimal locations and size of capacitor with an objective of improving the voltage profile and reduction of power loss.

In [4], the problem of optimally placing fixed and switched type capacitors in a radial distribution network is solved using conic MINLP approach. A new method was proposed in [5] to optimize locating and the size of fixed and switching capacitor banks based on bacterial foraging (BF) oriented by particle swarm optimization (PSO) algorithm (BF-PSO). The unbalanced and nonlinear loads, capacitor installation cost, network total harmonic distortion (THD) index, and the deviation of the voltage fundamental component from the permitted value were considered in the analysis.

In this paper, a heuristic optimization method is proposed for solving the problem of capacitor placement and sizing in distribution networks.

2. Problem formulation

The problem formulation for optimal capacity allocation is described in this section.

2.1 Decision variables

The number of installed capacitor bank in each bus is defined as the decision variable, i.e. ξ_i^c .

2.2 Power flow constraints

Besides the economic assumptions and calculations made till now, it is necessary that the technical constraint are also satisfied. The most viable constraints are well known power flow equations that shall be satisfied for each configuration and demand level as indicated in (1).

$$P'_{i,h} = V_{i,h} \sum_{j=1}^{n} Y_{ij} V_{j,h} \cos\left(\delta_{i,h} - \delta_{j,h} - \theta_{ij}\right)$$

$$Q'_{i,h} = V_{i,h} \sum_{j=1}^{n} Y_{ij} V_{j,h} \sin\left(\delta_{i,h} - \delta_{j,h} - \theta_{ij}\right) \qquad (1)$$

$$V_{\min} \le V_{i,h} \le V_{\max}$$

Where, $P'_{i,h}$ is the net active power injected to bus i, in demand level h. $Q'_{i,h}$ is the net reactive power injected to bus i, in demand level h. $V_{i,h}$ is the voltage magnitude of bus i in demand level h. $V_{\max}$ is the maximum permissible voltage in the network and $V_{\min}$ is the minimum permissible voltage in the network.

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2.3 Objective functions

Distribution systems are usually designed with just one supply source and this may cause significant active and reactive losses. The active losses mainly depend on the line resistance and currents and are usually referred to as thermal losses. While the line resistances are fixed, the currents are a complex function of the system topology and the location/size of capacitor banks and system demand level.

$$TLC = \sum_{h=1:N_h} C_h \times AL_h \times DU_h \quad (2)$$

Where, AL_h is the active loss in demand level h and TLC is the total active loss costs, C_h is the cost of active loss in demand level h.

The installation cost of capacitor banks is calculated as the sum of costs associated to all installed capacitors over all buses of the network.

$$IC = \sum_{bus} \xi_i^c \times C_{cap} \quad (3)$$

Where, IC is the total investment cost of capacitor banks and C_{cap} is the investment cost of a each individual capacitor. The final objective function is obtained by adding all the introduced cost components. This is done in (4).

$$OF = TLC + IC \quad (4)$$

3. Proposed algorithm

The Imperialist Competition Algorithm (ICA) was first proposed in [18]. This algorithm starts with an initial population called colonies. The colonies are then categorized into two groups namely, imperialists (best solutions) and colonies (rest of the solutions). The imperialists try to absorb more colonies to their empire. The colonies will change according to the policies of imperialists. The colonies may take the place of their imperialist if they become stronger than it (propose a better solution). This algorithm has been successfully applied to PSS design [6] and data clustering [7]. The flowchart of proposed algorithm is depicted in Fig.1. The steps of the proposed Imperialist Competition Algorithm (ICA) are described as follows:

- Step 1. Generate an initial set of colonies with a size of N_c.
- Step 2. Set Iteration=1.
- Step 3. Calculate the objective function for each colony using (4) and set the power of each colony as follows:

CP_c = OF (5)

This means the less OF is, the more stronger IP_i is.

- Step 4. Keep the best N_{imp} colonies as the imperialists and set the power of each imperialist as follows:

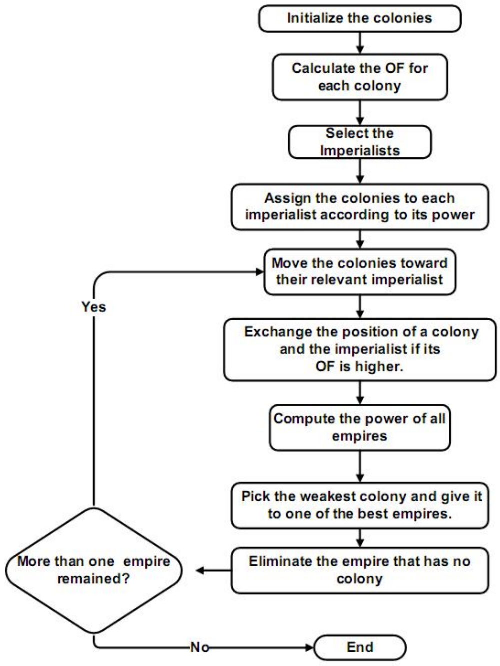
IPi = OF (6)

- Step 5. Assign the colonies to each imperialist according to the calculated IP_i.
- Step 6. Move the colonies toward their relevant imperialist using crossover and mutation operators.
- Step 7. Exchange the position of a colony and the imperialist if it is stronger ($CP_c > IP_i$).
- Step 8. Compute the empire's power, i.e. EP_i for all empires as follows:

$$EP_i = \frac{1}{N_{E_i}} (w_1 IP_i + w_2 \sum_{c \in E_i} CP_c) \quad (7)$$

where w_1 and w_2 are weighting factors which are adaptively selected.

- Step 9. Pick the weakest colony and give it to one of the best empires (select the destination empire probabilistically based on its power (EP_i).
- Step 10. Eliminate the empire that has no colony.
- Step 11. If more than one empire remained then go to Step. 6
- Step 12. End.



The flowchart of proposed Imperialist Competition Algorithm

4. SIMULATION RESULTS

The proposed IGA algorithm has been applied to examine the capacitor allocation problem on the 69-bus [8] distribution network. This network is a 12.66-kV, system, which has a substation, 69 load buses, and 74 branches.

The cost of capacitor banks is assumed to be 3 US$/kVAr [8]; The value of loss costs is assumed to be 0.06 US$/kWh for all the three load levels was adopted. The load levels and their duration are specified in Table I. The size of available capacitor banks is assumed to be 100kVar.

TABLE I: demand level values and their associated duration

Demand level	Demand level factor	Duration (h)
Light	0.5	2000
Medium	1	5260
Heavy	1.6	1500

Table II shows the capacitor placement locations and sizes. The switching patterns of the installed capacitors are also specified.

TABLE II: The capacitor placement scheme obtained by the proposed algorithm

Bus	Light	Medium	Heavy
2	700	200	200
3	0	100	200
4	100	0	0
5	0	100	0
6	0	100	0
7	100	100	0
11	0	100	100
17	0	0	100
19	0	200	100
37	100	100	200
39	100	0	100
42	0	0	100
46	0	0	100
55	0	0	100
58	100	0	0
59	100	100	500
60	0	100	200
61	100	200	300
62	0	300	300
63	100	0	100
64	100	400	600
66	0	100	100
67	100	0	100

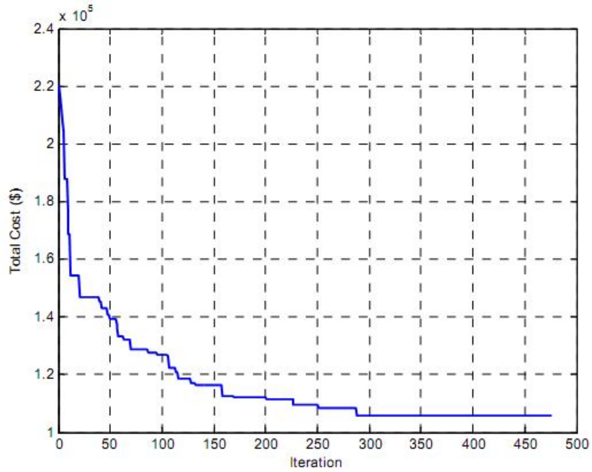


Fig. 1: Convergence of the proposed solution to the optimal solution

Table III shows the comparison of the results with and without considering capacitor placements. The total cost for the system without any compensation is
US $135,905. After compensation, the total cost would be 103.122.26 $. The total saving is 32,782.74 $.

TABLE III: The comparison between the placement schemes of the proposed algorithm and other methodologies.

Load level	Active Loss (KW)		
	Base case	[8]	Proposed ICA
Light	51.60	40.48	34.77
Medium	224.96	156.62	145.43
Heavy	652.40	460.45	406.13
Total loss Cost	135,905.00	95,727.00	86,622.26
Investment cost	-	9,300.00	16,500.00
Total Cost	135,905.00	105,027.00	103,122.26
Total Saving	-	30,878.00	32,782.74

Conclusion

This study has presented an ICA method for optimal capacitor placement for reducing the total costs in a distribution system. The objectives considered attempts to minimize the total cost including active loss cost and also the investment costs. The simulation on a medium size distribution network has proved the feasibility of the proposed approach. The obtained results are quite better than previously published results.

REFERENCES

[1] S.M. Tabatabaei, B. Vahidi, "Bacterial foraging solution based fuzzy logic decision for optimal capacitor allocation in radial distribution system", Electric Power Systems Research, Volume 81, Issue 4, April 2011, Pages 1045-1050.

[2] Seyed Abbas Taher, Ali Karimian, Mohammad Hasani, A new method for optimal location and sizing of capacitors in distorted distribution networks using PSO algorithm, Simulation Modelling Practice and Theory, Volume 19, Issue 2, February 2011, Pages 662-672.

[3] R. Srinivasas Rao, S.V.L. Narasimham, M. Ramalingaraju, Optimal capacitor placement in a radial distribution system using Plant Growth Simulation Algorithm, International Journal of Electrical Power & Energy Systems, Volume 33, Issue 5, June 2011, Pages 1133-1139.

[4] R.A. Jabr, Optimal placement of capacitors in a radial network using conic and mixed integer linear programming, Electric Power Systems Research, Volume 78, Issue 6, June 2008, Pages 941-948.

[5] H. Mohkami, R. Hooshmand, A. Khodabakhshian, Fuzzy optimal placement of capacitors in the presence of nonlinear loads in unbalanced distribution networks using BF-PSO algorithm, Applied Soft Computing, Volume 11, Issue 4, June 2011, Pages 3634-3642.

[6] A. Jalilvand, S. Behzadpoor, and M. Hashemi, "Imperialist competitive algorithm-based design of pss to improve the power system," in Power Electronics, Drives and Energy Systems (PEDES) 2010 Power India, 2010 Joint International Conference on, 2010, pp. 1 –5.

[7] T. Niknam, E. T. Fard, N. Pourjafarian, and A. Rousta, "An efficient hybrid algorithm based on modified imperialist competitive algorithm and k-means for data clustering," Engineering Applications of Artificial Intelligence, vol. 24, no. 2, pp. 306 – 317, 2011.

[8] D. Das, Optimal placement of capacitors in radial distribution system using a Fuzzy-GA method, International Journal of Electrical Power & Energy Systems, Volume 30, Issues 6-7, July-September 2008, Pages 361-367.