Ain Shams Engineering Journal (2016) 7, 907–916

Ain Shams University

Ain Shams Engineering Journal

www.elsevier.com/locate/asej
www.sciencedirect.com

ELECTRICAL ENGINEERING

Optimal placement of capacitors in radial distribution system using shark smell optimization algorithm

N. Gnanasekaran [a,*], S. Chandramohan [b], P. Sathish Kumar [c], A. Mohamed Imran [d]

[a] *Department of Electrical and Electronics Engineering, Misrimal Navajee Munoth Jain Engineering College, Chennai 600097, India*
[b] *Department of Electrical and Electronics Engineering, Anna University, Chennai 600025, India*
[c] *Embedded Technology Solutions, Chennai 600100, India*
[d] *School of Electrical Engineering, VIT University, Chennai Campus, Chennai 600127, India*

Received 23 October 2015; revised 18 December 2015; accepted 14 January 2016
Available online 6 February 2016

KEYWORDS

Distribution system;
Energy loss;
Capacitor placement;
Shark smell optimization algorithm

Abstract Optimal size and location of shunt capacitors in the distribution system plays a significant role in minimizing the energy loss and the cost of reactive power compensation. This paper presents a new efficient technique to find optimal size and location of shunt capacitors with the objective of minimizing cost due to energy loss and reactive power compensation of distribution system. A new Shark Smell Optimization (SSO) algorithm is proposed to solve the optimal capacitor placement problem satisfying the operating constraints. The SSO algorithm is a recently developed metaheuristic optimization algorithm conceptualized using the shark's hunting ability. It uses a momentum incorporated gradient search and a rotational movement based local search for optimization. To demonstrate the applicability of proposed method, it is tested on IEEE 34-bus and 118-bus radial distribution systems. The simulation results obtained are compared with previous methods reported in the literature and found to be encouraging.

1. Introduction

Distribution systems normally consist of a main feeder and lateral distributors. It acts as a link between high voltage transmission line and the low voltage consumers. The low voltage and high current characteristics of distribution system leads to high power losses compared to that of transmission system. About 13% of total power generated is consumed as power losses at the distribution system [1]. The power losses can be separated into two parts based on the active and reactive components of branch currents. The losses produced by reactive

* Corresponding author. Tel.: +91 9444770231.
E-mail addresses: ngnanasekaran69@gmail.com (N. Gnanasekaran), c_dramo@annauniv.edu (S. Chandramohan), sathish07ee@gmail.com (P.S. Kumar), mohamedimran.a@vit.ac.in (A. Mohamed Imran).
Peer review under responsibility of Ain Shams University.

Production and hosting by Elsevier

http://dx.doi.org/10.1016/j.asej.2016.01.006

Nomenclature

v_n	voltage at *n*th bus
v_{min}	minimum voltage of the system in p.u.
$r_{n,\ n+1}$	resistance of branch connecting buses '*n*' and '*n* + 1'
$x_{n,\ n+1}$	reactance of branch connecting buses '*n*' and '*n* + 1'
P_{TLoss}	total real power loss of the system
nb	number of branches
K_e	cost of energy losses in \$/kW h
T	time duration (8760 h)
σ	depreciation factor
K_{ins}	installation cost of capacitor in \$ per node
NC	number of buses for capacitor placement
K_c	purchase cost of capacitor in \$ per kVAr
K_{ope}	operating cost of capacitor in \$ per year per node
$v_{n,\ min}$	minimum permitted voltage at *n*th bus in p.u.
$v_{n,\ max}$	maximum permitted voltage at *n*th bus in p.u.
Q_T	total reactive power demand of system in kVAr
Q_{cn}	reactive power injection at bus-*n* in kVAr
$Q_{cn,min}$	minimum reactive power compensation in kVAr
$Q_{cn,max}$	maximum reactive power compensation in kVAr
X	position of sharks (solution vector)
NP	population size
ND	number of elements/dimensions of each solution
V	vector representing velocity of sharks
k_{max}	number of iterations for SSO
$R1,\ R2$	uniform random numbers in the interval [0, 1]
g	gradient scaling factor
α_k	inertial constant, $\in[0, 1]$
β_k	velocity limiter ratio
$R3$	random number from uniform distribution in the interval [−1, 1]
M	rotational movement variable

components of branch currents can be reduced by the installation of shunt capacitors. Capacitive compensation reduces power loss, improves voltage profile of system, increases the power factor and releases kVA capacity of distribution equipments for additional load growth. The most critical factors that influence the technology and economical impacts of capacitor placement problem are the type, size and location of shunt capacitors in distribution systems. The objective of the optimal capacitor placement problem is to find the optimal locations, type and size of capacitors to be placed on the Radial Distribution System (RDS). Optimal capacitor placement is a complex combinatorial problem. Analytical methods [2,3] have been used in most of the early works of optimal placement of capacitors which require no powerful computing resources. Simulated Annealing (SA) is an iterative optimization algorithm which is based on the annealing of solids. SA has been used to minimize capacitor installation costs in [4]. Heuristic search strategies [5,6] were implemented to find solution to the capacitor placement problem using heuristic rules which searches through a set of possible solutions.

In the recent years optimal placement of capacitor problems has been solved using population based optimization algorithms such as Genetic Algorithm [7], Particle Swarm Optimization algorithm [8], Artificial Bee Colony (ABC) algorithm [9,10] and Cuckoo Search Algorithm (CSA) [11]. In [12], a direct search algorithm has been proposed to find optimal locations and optimal sizes of fixed and switched capacitors. An evolutionary algorithm called modified cultural algorithm has been implemented to the optimal capacitor allocation problem in [13]. In [14], a combination of Fuzzy-GA approach is presented to find the optimal sizes of fixed and switched capacitors. Plant growth simulation algorithm is based on the process of plant growth and has been applied to find the optimal size of capacitors to the identified candidate buses in [15].

Shark smell optimization algorithm is a new metaheuristic algorithm based on ability of shark to find prey. The effectiveness of SSO algorithm has been proven by comparing it with many other heuristic optimization methods after implementing it to the bench mark functions [16]. The main contribution of this paper is application of SSO algorithm to optimal capacitor placement problem. In this paper, the shark smell optimization algorithm has been proposed for finding optimal locations and sizes of shunt capacitors. The objective function has been considered as minimization of cost function. Size of capacitor banks is taken as discrete values.

2. Problem formulation

2.1. Power flow equations

Distribution load flow plays an important role in finding solution for capacitor placement problem. Generally distribution networks are radial and the R/X ratio is very high. Hence, the conventional Gauss Seidel, Newton–Raphson and Fast Decoupled load flow methods are inefficient in solving such networks. The distribution load flow algorithm proposed in [17] has been used in this paper.

Distribution system power flow is calculated by a set of recursive equations derived from single line diagram shown in Fig. 1.

Equivalent current injection at the *n*th bus is calculated as

$$I_n = \left(\frac{S_n}{v_n}\right)^* = \left(\frac{P_n + jQ_n}{v_n}\right)^* \tag{1}$$

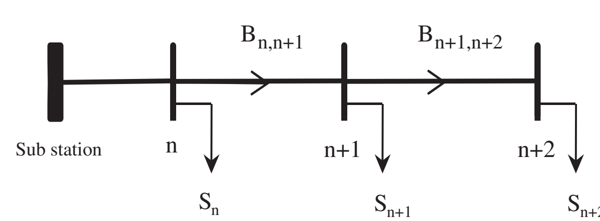

Figure 1 Single line diagram of a sample system.