Available online at www.sciencedirect.com

ScienceDirect

Energy Procedia 75 (2015) 1153 – 1158

Energy Procedia

The 7th International Conference on Applied Energy – ICAE2015

New Sensitivity based Approach for Optimal Allocation of Shunt Capacitors in Distribution Networks using PSO

Neeraj Kanwar[a], Nikhil Gupta[a], Anil Swarnkar[a], K. R. Niazi[a], R.C. Bansal[b*]

[a]*Department of Electrical Engineering, Malaviya National Institute of Technology, Jaipur, 302017, India*
[b]*Department of Electrical, Electronics and Computer Engineering, University of Pretoria, South Africa*

Abstract

This paper proposes a new methodology for optimal allocation of shunt capacitors in distribution systems. The proposed method combines various objectives and constraints into a Comprehensive Constraint Multi-objective Function. The function has been optimized using a Particle Swarm Optimization (PSO) based method. Attempts have also been made to improve the performance of PSO. The search space of PSO is reduced by introducing a new reactive power flow sensitivity approach that determines the set of candidate nodes suitable for capacitor placement and also by employing a new constrained particle structure. The proposed method is tested on a 69-bus test distribution system and the application results are promising.

Peer-review under responsibility of Applied Energy Innovation Institute

Keywords: capacitor placement; distribution systems; sensitivity analysis; particle swarm optimization; reactive compensation.

1. Introduction

The present trend towards competitive business environment enforces electric utilities to enhance their annual profits while ensuring reliable and better quality of electric supply. Benefits such as reduction in annual energy loss, improvement in node voltage profiles, system capacity release, etc. depend greatly on how optimally shunt capacitors are installed. In the context of modern distribution, the aim of the capacitor placement problem is to maximize the profit on the investment of capacitor placement, subject to operational & power quality constraints.

* Corresponding author. Tel.: +27 12 4205446; fax: +27 12 3625000.
E-mail address: rcbansal@ieee.org.

Peer-review under responsibility of Applied Energy Innovation Institute
doi:10.1016/j.egypro.2015.07.546

In recent years population based meta-heuristic techniques such as Genetic Algorithm, Particle Swarm Optimization (PSO), Teaching Learning Based Optimization, Plant Growth Simulation Algorithm, Artificial Bee Colony, Micro-Genetic Algorithms, etc. [1-8] have been applied to solve this problem. PSO is modern swarm intelligence based search technique and has several advantages in term of simplicity, convergence speed, and robustness [9]. However, its performance is greatly depends on its parameters tuning and it often suffers from the problems such as being trapped in local optima due to premature convergence [10], lack of efficient mechanism to treat the constraints [11], loss of diversity and performance in optimization process [12], etc. In order to enhance its exploration and exploitation potentials, the problem search space should be intelligently selected.

In this paper, the search space of PSO is squeezed by proposing a new reactive power flow based sensitivity method and also by introducing a constrained particle structure. The capacitor placement problem is solved by suggesting a comprehensive constraint multi-objective function (CCMF) which considers loss reduction, voltage profile improvement, feeder overloading, kVA enhancement etc., in such a way that the annual savings is maximized. The proposed method is applied on a standard 69-bus test distribution system and the results are promising when compared with other existing methods.

2. Problem formulation

The proposed CCMF for the optimal allocation of shunt capacitor is as given below:

$$Max\ \ F(x)=k_1\left(K_e\sum_{j=1}^{N_L}T_j\Delta E_j+K_p\Delta P+K_S\Delta S_{CR}\right)\times \mathrm{PF}-\sum_{i=1}^{nc}K_{ci}Q_{ci} \tag{1}$$

Where, the first term within the bracket represents annual cost of energy loss reduction, second term represents the annual cost of peak power loss reduction and the third term represents the annual cost of the substation capacity release. The negative term represents annual charges on capacitor placement. The term penalty function (PF) is explained as under.

2.1. Penalty Function

The PF in (1) is incorporated to check node voltage and feeder current constraints and is defined by the geometric mean of node voltage deviation and feeder current deviation penalty functions as below

$$PF = \sqrt{(V_{pf} \times I_{pf})} \tag{2}$$

$$V_{pf} = 1/(1+k_2\ (Max\ (\Delta V_{ij\max}))) \tag{3}$$

2.2. Operating Constraints

- Power flow balance constraint

$$H(x,u)=0 \tag{4}$$

- Capacitor capacity and control setting constraint

$$Q_{ci} \le LQ_o;\ L= 0, 1, 2, \dots, nc \tag{5}$$

$$Q_{ci} = k\Delta Q;\ k = 0, 1, 2, \dots, Q_{ci}/\Delta Q \tag{6}$$

$$\sum Q_{ci} = Q_D \tag{7}$$

The CCMF defined by (1) is optimized using a proposed PSO based method. The above problem is