Electric Power Systems Research 80 (2010) 642–650

Contents lists available at ScienceDirect

Electric Power Systems Research

journal homepage: www.elsevier.com/locate/epsr

Optimal allocation of capacitors in unbalanced multi-converter distribution systems: A comparison of some fast techniques based on genetic algorithms

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ARTICLE INFO

Article history:
Received 16 July 2008
Received in revised form 30 April 2009
Accepted 25 October 2009
Available online 3 December 2009

Keywords:
Optimal allocation of capacitors
Genetic algorithms
Inherent Structure Theory of Networks
Sensitivity analysis
Micro-genetic algorithms

ABSTRACT

Genetic algorithms (GAs) are widely used for optimal allocation of capacitors in distribution systems. When dealing with large-scale systems, such as in case of unbalanced multi-converter distribution systems, these algorithms can require significant computational efforts, which reduce their effectiveness. In order to reduce processing time for GAs and simultaneously maintain adequate levels of accuracy, methods based on the reduction of the search space of GAs or based on micro-genetic algorithms have been proposed. These methods generally guarantee good solutions with acceptable levels of computational effort. In this paper, some fast, GA-based methods are compared and applied for solving the problem of optimal sizing and siting of capacitors in unbalanced multi-converter distribution systems. The algorithms have been implemented and tested on the unbalanced IEEE 34-bus test distribution system, and their performances have been compared with the performance of the simple genetic algorithm technique.

1. Introduction

In this paper, the problem of determining the optimal sizing and location of capacitors in distribution systems is considered. This is a typical example of a large-scale, mixed, non-linear, constrained, optimization problem, since the solution should take into account various operational and equipment limits.

The objective of the capacitor placement is either to minimize the total costs (i.e., costs of capacitors and losses) or to optimize the voltage profile, and to make sure that these capacitors will have the minimum impact on the waveform distortion of the bus voltages in the distribution system. This is due to the possibility of unwanted over-voltages that may be caused by harmonic resonance due to the presence of static converters in the system. Furthermore, the facts that distribution systems can operate with unbalanced loading conditions and can be characterized by the presence of feeders with missing phases mean that the optimization will have to account for any unbalances in the system.

Then, the optimal placement of capacitors should be formulated with reference to an unbalanced multi-converter distribution system.

Such problems can be solved by using GAs that have been proven to find good solutions for sizing and locating capacitors [1–9]. However, as the system size increases, as is the case for unbalanced systems in which the waveform distortions have to be taken into account, the solution of this problem by GAs requires extensive calculation capacity and time, making efforts to produce fast solution procedures important.

In order to reduce processing time while maintaining reasonable accuracy, methods based on the reduction of GA search space or micro-genetic algorithms can be used.

A reduced feasible region, i.e., the search space, can be determined by means of sensitivity structures [8,9] or by fuzzy logic [10]; therefore, the optimization problem is faced in two steps, i.e., (1) determine the reduced feasible region (i.e., the reduced set of candidate busbars for the capacitor location) and (2) find the optimal solution in this reduced region, f.i. applying a simple genetic algorithm.

In this paper, two different approaches for the reduction of the feasible region are assessed. The first approach is based on the Inherent Structure Theory of Networks (ISTN); this Theory, which is based on the spectral representation of the admittance matrix, helps identify the individual candidate busbars at which the connection of a capacitor will give the maximum improvement of the voltage profile. The ISTN is based on the reformulation of network admittance and impedance matrices with respect to their eigenvalues and eigenvectors, and the Theory was first proposed by

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doi:10.1016/j.epsr.2009.10.029