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Reconfiguration of distribution networks to minimize loss and disruption costs using genetic algorithms

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ABSTRACT

In this paper a computational implementation of an evolutionary algorithm (EA) is shown in order to tackle the problem of reconfiguring radial distribution systems. The developed module considers power quality indices such as long duration interruptions and customer process disruptions due to voltage sags, by using the Monte Carlo simulation method. Power quality costs are modeled into the mathematical problem formulation, which are added to the cost of network losses. As for the EA codification proposed, a decimal representation is used. The EA operators, namely selection, recombination and mutation, which are considered for the reconfiguration algorithm, are herein analyzed. A number of selection procedures are analyzed, namely tournament, elitism and a mixed technique using both elitism and tournament. The recombination operator was developed by considering a chromosome structure representation that maps the network branches and system radiality, and another structure that takes into account the network topology and feasibility of network operation to exchange genetic material. The topologies regarding the initial population are randomly produced so as radial configurations are produced through the Prim and Kruskal algorithms that rapidly build minimum spanning trees.

1. Introduction

Most of the overhead electric power distribution systems must operate in radial configurations. Normally open and normally closed switches are located along the network in strategic points. By altering the topology to a different radial configuration, one might obtain losses reduction, improvement in the network voltage profile, and betterment of reliability indices. When a fault occurs, the fault block can be isolated and a new radial configuration might restore the rest of the load.

The reconfiguration problem that determines the best possible configuration considering the above criteria and constraints can be modeled as a non-linear mixed integer problem, what produces an enormous search space due to the combinatory nature of the problem. Many approaches have been considered to address such a problem, particularly conventional integer programming algorithms, heuristic algorithms and mixed heuristic-combinatory algorithms to better explore the search space [1–11].

In this paper, the reconfiguration of distribution networks, considering power quality indices, is formulated as a non-linear mixed integer programming problem. The adopted solution technique consists in an evolutionary algorithm (EA) that considers a decimal base codification scheme. The EA makes use of recombination and mutation operators specially developed to maintain alternative radial configuration networks.

Fitness functions are related to network losses and penalizations regarding voltage and loading constraints. The model described in this paper also handles power quality costs, namely long duration interruptions (greater or equal to 1 min) and customer process interruptions due to voltage sags, herein simply named as disruptions. An efficient power flow method [3] and [12] determines network losses, equipment loading and bus voltages for different network topologies. As for the power quality indices, a Monte Carlo simulation method [13] was implemented and incorporated into the optimization model.

Other relevant aspects which are discussed in this paper regard the implementation of solutions that directly affect the efficiency of the evolutionary algorithm, namely the generation of the initial population, the EA codification scheme and the recombination operator.

Concerning the EA selection procedure, two possible alternatives are analyzed, namely tournament and elitism. The latter one considers the saturation of the elite population over the generation cycles.

The effects of the EA control parameters in the performance of the evolutionary algorithm, such as the size of the population and the recombination and mutation rates, are carefully studied and analyzed.

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