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A simpler and exact mathematical model for the computation of the minimal power losses tree

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ABSTRACT

This paper presents a new model to compute the tree of minimum active power losses in distribution systems. The main idea consists of using a non-conventional group of variables instead of the classical bus complex voltages, in addition to algebraically formulating the topological and electrical constraints before the actual radial configuration is determined. The new variables allow to set out a simpler mathematical optimization problem where, additionally, the product of continuous and binary variable does not appear, so one of the main problems related to the mathematical reconfiguration problem is avoided. The final minimization problem is made up of linear and quadratic equality and inequality constraints, also being linear the objective function. The new proposed model has been tested on different systems used specifically in the literature. In all the cases the reached solution matches the better known and even in same cases it has been improved.

1. Introduction

The reconfiguration problem is one of the most classical optimization problems in both planning and operation of distribution systems. There are a great variety of reconfiguration problems depending on the objective function: minimization of power losses, energy loss reduction and fast service restoration are some of them, being the former the most popular. One key factor when practically implementing those optimization problems refers to the fact that, while distribution networks are structurally meshed, they are radially operated. In fact, most optimization problems are simply aimed at finding the best radial configuration, among a huge number of combinations, for which efficient procedures to check or enforce radiality are needed.

This paper is focused on solving the distribution system reconfiguration problem for system loss reduction. A survey of the state of the art on this topic was published in [1], where authors propose a classification by the employed solution methodology: those based upon a blend of heuristics and optimization methods, those making use of heuristic alone, and those using some from of artificial intelligence. From then a great number of new solutions have been proposed, most of them around the artificial intelligence group, as are references [2–16]. Due to the magnitude of the problem and its non-linear nature, the use of a blend of optimization and heuristic techniques continue being one of the most popular way to solve the problem, particularly if the reconfiguration tool is intended for real-time application. This is the case of references [17–24]. Looking for avoiding the combinatorial nature of the problem, researchers have explored purely heuristic solution techniques [25–34]. Next, a review of these new references follows by considering the same previous classification assumed in [1].

Intelligent techniques group a large number of families: evolutionary algorithms, fuzzy logic, artificial neural networks, tabu search, ant colony, etc. On one hand, intelligent algorithms are computationally expensive and attention to a good implementation is forced if local optimums want to be avoided. On the other hand, these modern heuristic techniques are very suitable for solving large-scale combinatorial optimization problems. In this group, references [2–7] are some examples of based evolutionary programming reconfiguration techniques. The authors of [2] propose to use evolutionary programming along with fuzzy logic to speed up the evolutionary process by adjusting the mutation rate; a 16-bus system is the only tested case. In reference [3] fuzzy logic is also incorporated to a genetic algorithm in order to deal with a multiobjective function where minimizing power losses is one of its terms. The proposed codifications in these two works have been improved in more recent publications such as references [4–6]. All of these three last works try to reduce running time. In reference [4] a tree encoding and two genetic operators are proposed and applied to different-sized systems; the solution methodology looks like quite fast. A codification strategy based on keeping system loops is proposed in [5] to computationally improve a based-genetic reconfiguration algorithm. Later, in the thrid work [6] a similar codification strategy than that considered in [5] is implemented, but

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