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A Multi-Objective Evolutionary Algorithm with Efficient Data Structure and Heuristic Initialization for Fault Service Restoration

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Abstract

Service restoration in energy distribution systems is a complex optimization problem with many restrictions. After a fault occurrence, the challenge is obtain a service restoration plan reconnecting all the healthy out-of-service areas satisfying all the operational and technical constraints. Recent works have study the use of meta-heuristics in order to find a sub-optimal solution with low computational complexity. One of these works include the use of a multi-objective algorithm with a new data structure called node depth encoding. This paper proposes and analyses the use of a new heuristic initialization procedure to be used with node depth encoding which guarantees the analysis of all possible solutions considering only a restricted number of switches incident to the out-of-service areas. The proposed methodology is evaluated by applying it to the real and large-scale distribution system of Londrina city (Brazil). The results showed that the new heuristic improves the overall performance reducing the number of switches operations to reconfigure the distribution system.

Keywords: Evolutionary Algorithm, Optimization, Real World Problem

1 Introduction

Fault service restoration is a important task in energy distribution system. After the identification of a faulted zone, a proper plan to network reconfiguration is applied to change the topological structure of distribution system by opening sectionalizing (Normally Closed - NC) switches and closing tie (Normally Open - NO) switches. When the reconfiguration plan is executed, the main objectives are to minimize both the number of out-of-service areas and the

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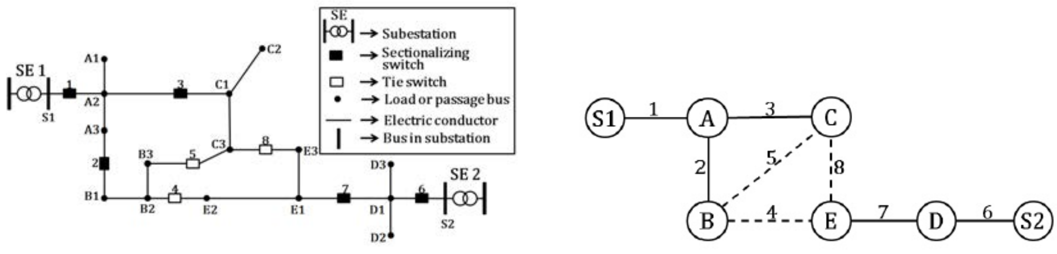
number of switching operations without violating the radial structure of the network and operational constraints (limits for node voltage, network loading, and substation loading). In general, most of the works for this problem is based on heuristic and meta-heuristics [1, 2] algorithms. However, the most of these methodologies demand long running time when applied to large-scale distribution system with thousands of buses and switches. The methodology proposed in [2] overcomes this hurdle combining Multiple-Objective Evolutionary Algorithms (MOEAs) with the tree encoding named Node-Depth Encoding (NDE) [3]. The proposed solution generated adequate service restoration plans a real and large-scale distribution system without requiring any network simplification. However, in a group of fault cases the results can be improved.

In this paper we propose a algorithm called (MEA-H: Multi-objective Evolutionary Algorithm with Heuristic) to improve the results obtained by [1] and [2]. This heuristic incorporating in the first stage of multi-objective evolutionary algorithm an combinatorial search procedure over the data structure node depth encoding evolving only switches incident to the out-of-service areas, called as Tier 1 tie switches [4]. It guarantees the analysis of all possible configurations, that restore the service to the healthy out-of-service customers, considering only the Tier 1 tie switches.

2 Distribution System Representation Using Node-Depth Encoding

For problems involving network reconfiguration in distribution systems, as the service restoration problem, the distribution electrical network is considered as a collection of components interconnected electrically by conductors and switches. Consequently, for service restoration problem the distribution system is usually represented by a graph, that is, by a set of nodes (or vertices) connected by edges. The electrical network can be viewed as a set of sectors (which can are composed by electric conductors, load and passage buses, etc.) interconnected by switches.

Figure 1(a) highlights the main components of an illustrative and typical DS with two Feeders. Figure 1(b) presents the graph representation of this DS, where the nodes symbolize the sectors, edges in solid lines symbolize NC switches and edges in dashed lines symbolize NO switches. Observe that the two feeders of this DS (Figure 1(a)) are represented by two graph trees formed by the solid lines in Figure 1(b). The nodes $S1$ and $S2$ in the graph are the root nodes of trees 1 and 2. These nodes correspond to the buses $S1$ and $S2$, which are, respectively, in substations 1 and 2.



(a) Example of an illustrative typical DS with two feeders.

(b) Representation of the DS of Figure 1(a) by a graph.

Figure 1: Distribution system and its graph representation.

The NDE is basically a graph tree representation in a linear list containing the tree nodes