Multiobjective Discrete Differential Evolution for Service Restoration in Energy Distribution Systems

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ABSTRACT

This paper presents a new multiobjective discrete differential evolution for service restoration in distribution systems. The proposed approach was compared with other five multiobjective evolutionary algorithms (MOEAs), which use Node-Depth Encoding (NDE). The proposed approach have been evaluated taking into account the switching operations necessary to find adequate restoration plans considering multiple non-linear constraints and objective functions. The MOEAs used in this paper have been employed to solve four different datasets with 3,860, 7,720, 15,440 and 30,880 buses, respectively. Simulations results have shown that proposed approach reached good solutions with low switching operations and reduced running time when compared with others MOEAs.

Keywords

Large-Scale Distribution Systems, Service Restoration, Node-depth Encoding, Multi-Objective Evolutionary Algorithms, Differential Evolution.

1. INTRODUCTION

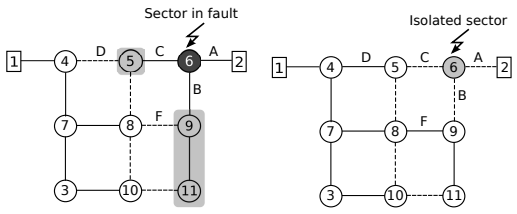
Many real-world systems involve multiobjective optimization in their operation. Multiobjective optimization problems (MOPs) require the simultaneous optimization of several non-commensurate and often competitive/conflicting objectives. Distribution System problems, such as service restoration, usually involve network reconfiguration procedures. As a consequence, they can be considered Distribution System Reconfiguration (DSR) problems, which are usually formulated as multiobjective and multiconstrained optimization problems [5].

The performance obtained by EAs for large-scale DS is dramatically affected by the data structure used to represent the electrical topology of the DSs. For this reason, the Node-depth encoding (NDE) [1] was proposed to improve the performance of MOEAs for service restoration in large-scale distribution systems problems.

The study reported in this paper proposes an extension of successful Diferential Evolution (DE) using NDE adapted for the SR problem, called Multiobjective Discrete Differential Evolution based on NDE (MODE/NDE). Moreover, the results obtained with MODE/NDE were compared with others five diffrent MOEAs described as follow: NSGA-II with NDE (NSGA/N) [3], MOEA with SubpopulationTables (MEAN) [5], MOEA based on Decomposition and NDE (MOEA/D) [4], MEAN with a Discrete Differential Mutation Operator (MEAN/DE) [4] and MOEA based on NDE with crowding distance and strength pareto (MEA2N/STR) [2]. Thus, this paper provides a detailed assessment of six MOEAs based on NDE with different features applied to SR problem.

2. SERVICE RESTORATION PROBLEM

After the faulted areas have been identified and isolated, the out-of-service areas must be connected to other feeders by closing and/or opening switches. Fig. 1(a) shows an example of DSR in a DS with two feeders. Nodes 1, and 2 represent power sources in a feeder, solid lines are Normally Closed (NC) switches, dashed lines are Normally Open (NO) switches, and each circle represents sectors matching Lines and buses without sectionalizing or tie-switches are inside a sector, thus, they are not shown in DS representations, similar to the one in Fig. 1(a).



(a) Sector 6 in fault. (b) New configuration with service restorated.

Figure 1: Example of service restoration.

3. PROPOSED APPROACH

The new approach proposed in this paper called Multiobjective Discrete Differential Evolution based on NDE (MODE/NDE) is an adaptation of MEAN/DE with an in-

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clusion of discrete crossover operator and additional subpopulation tables considering crowding distance ($S_{\mathcal{F}_1}$, $S_{\mathcal{F}_2}$ and $S_{\mathcal{F}_3}$) and strength pareto (S_{str}). The crossover operator proposed consists of the recombination of history of the applications of the PAO and CAO operators from two individuals. The history of the applications is obtained from Evolutionary History Recombination operator (EHR) [4]. Moreover, it's obtained a list of movements between the vector mutant and an individual randomly chosen to commom ancestor. As a result, the recombination of the movements produces a trial vector (U_i). In the proposed approach, the discrete recombination with probability $C_r \in [0, 1]$ is adopted. The recombination process between elements from the list of the movements is similar to binomial crossover of the classic Differential Evolution algorithm.

4. TEST RESULTS

In order to analyze how the MODE/NDE approache behaves with the increase of the network size for the SR problem, the real Sao Carlos city DS (System 1 hereafter) was used to compose other three DSs with size varying from two to eight times the original DS. System 2 is composed of two Systems 1 interconnected by 13 NO new additional switches. System 3 is composed of four Systems 1 interconnected by 49 NO new additional switches. Finally, System 4 is composed of eight Systems 1 interconnected by 110 NO new additional switches. The experiments focus on comparing the six approaches according to the number of switching operations for SR plans, as described in Fig. 2. According to Fig. 2 MODE/NDE can deal with relatively complex networks finding lower number of switching operations and reaching the smallest number (seven) found for S1. In addiction, The MODE/NDE running time remained low for all datasets used (Fig. 3)

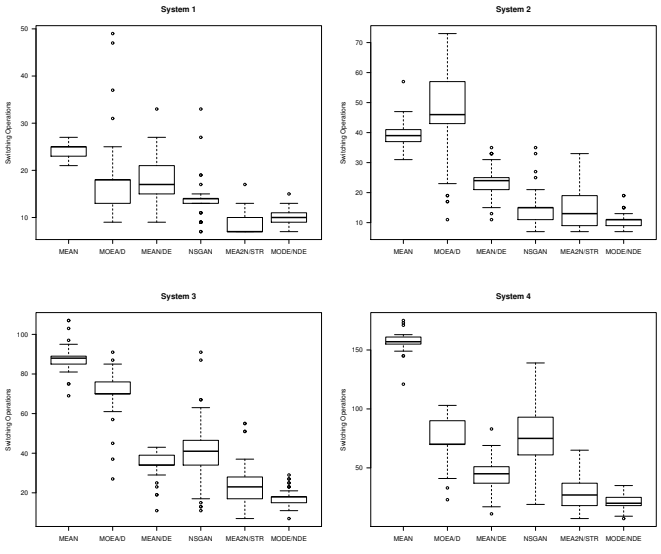

Figure 2: Simulations with Single Fault in Systems 1, 2, 3 and 4.

5. CONCLUSIONS

This paper proposed a new multiobjective discrete differential evolution based on NDE (MODE/NDE) for service restoration in distribution systems. The proposed approach was compared with others five multiobjective evolutionary algorithms, which also use NDE to solve the service restoration in distribution systems. According to experimental results MODE/NDE can deal with relatively complex networks finding lower number of switching operations and reduced running time for all datasets used.

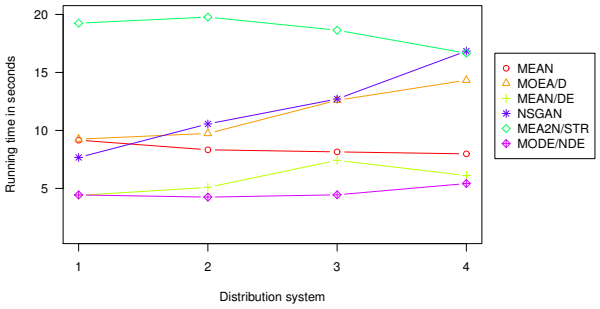

Figure 3: Running time average obtained from 50 trials for each dataset.

6. ACKNOWLEDGMENTS

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