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Research Article

Distribution Network Reconfiguration Simultaneously with Determining the Optimal Location and Capacity of Microturbines in Terms of Technical Issues Using Whale Optimization Algorithm and Fuzzy Technique

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Abstract

In this paper, to solve the multi-objective problem of distribution network reconfiguration in the presence of microturbines, the Whale algorithm has been proposed. In this field, the power losses and voltage profile improvement are the two most used objective functions in the literature. In addition to the mentioned objective functions, this paper also considers the optimal generation capacity of microturbines and reducing the fault current of the network lines to less than the rated fault current of the power switches. In this paper, the values of different objective functions are normalized by the fuzzy method. Since a set of candidate responses is created using Whale algorithm, the Fuzzy technique is used to determine the most optimal solution among the Pareto-optimal solutions. The proposed algorithm is implemented on IEEE 33-bus test system. The simulation results show the efficiency of the proposed algorithm in improving the considered objective functions. The proposed method, by establishing a suitable fit between different objective functions has introduced a more efficient structure with lower losses and voltage profile improvement, as well as the fault current passing through the lines. To verify the efficiency of the proposed algorithm, the multi-objective optimization issue is simulated with the PSO algorithm.

Keywords: Distribution network reconfiguration, Fuzzy technique, Microturbine optimization, Reducing the fault current, Whale optimization algorithm.

Highlights

- Considering reducing the fault current of the grid lines to less than the rated fault current of the power switches.
- Simultaneous consideration of three objective functions: reducing losses, improving voltage profiles, and reducing fault currents in network lines.
- Using the Pareto optimal method to reach multiple optimal solutions instead of a single optimal solution.
- Using fuzzy logic to find the most optimal answer from the set of optimal answers of the Pareto front method.
- Using a combination of the Whale algorithm, the Pareto optimal method, and the fuzzy technique to solve the issue.

Citation:
[in Persian].

1. Introduction

Electricity networks are undergoing significant changes and restorations due to several factors, including the aging of electrical components used in current systems, the introduction of innovative technologies in energy sources, information and communication sectors, limitation of fossil fuels, and increasing pressure to comply with environmental requirements. Therefore, with the help of distribution grid automation and its reorganization, the load feeding path can be changed, which can prevent wasting time and not feeding loads [1-3]. The location and size of DGs in a distribution grid may have a positive or negative impact on the performance of the grid. Therefore, their optimal location and size should be determined after comprehensive grid planning and study to avoid any negative effects such as overvoltage, overloading of network feeders, harmonic overload, etc. [4]. Distribution network reconfiguration can be simply defined as the process of changing the structure or configuration of the network by changing the state of open and closed switches in it. So that the radial structure of the network is maintained and all network loads are supplied while observing the network constraints. The main goal of network reconfiguration is to reduce power losses and reduce the overload of network feeders [5]. In [6], it focuses on the problems of optimal network reconfiguration, optimal distributed generation unit allocation with optimal power factor and unit power factor. A comprehensive review of recent papers on grid reconfiguration is provided in [7]. In [8], reconfiguring the distribution grid and using DG is performed compared to when only DG is used, which shows that power losses are reduced more effectively. Researchers in [9] studied the optimal location and size of DGs in a radial distribution network before and after reconfiguration. Here, a multi-objective PSO algorithm is used to determine the optimal location and size of DGs before and after reconfiguration of the radial network. In [10], the optimization problem is solved using an adaptive modified whale optimization algorithm. A new technique based on the depth-first search algorithm is used to address the radial constraints. The effectiveness of the proposed technique is tested on two standard distribution networks and its efficiency is proven.

2. Innovation and contributions

In this paper, a plan is proposed whereby the optimal location and capacity of microturbines are determined in such a way that the simultaneous combination of three objective functions, including reducing losses, improving the voltage profile, and reducing the fault current of the network lines to less than the rated fault current of the power switches, are correctly met. Network reorganization can also help to change the fault current passing through the lines. For this purpose, with the help of two load flow programs and short circuit calculations, these objective functions can be calculated and optimized. Therefore, the problem approach is considered as multi-objective. To solve this complex problem, a combination of the WOA and fuzzy technique is used. Since a set of candidate answers is generated using WOA, the fuzzy technique will be used to determine the appropriate answer from among them. In multi-objective problems, the objectives are inherently contradictory, so it is difficult to select the best answer from the resulting set of answers. Here, a fuzzy decision maker is used to determine the best response. Based on this concept, all the resulting response sets in the range of zero and one are evaluated using a linear membership function, and the response that has the highest membership function value for each of the objectives is selected as the most appropriate response. On the other hand, to verify the efficiency of the proposed algorithm, the multi-objective optimization problem is also simulated with the PSO algorithm.

Among the innovations of this paper, the following can be stated:

According to the authors' knowledge and review of articles in this field, the third objective function, namely reducing the fault current of the network lines to less than the nominal fault current that can be tolerated by the power switches, has been less addressed and is one of the innovations of the paper.

In previous papers, most of the objective functions including loss reduction and voltage profile improvement have been considered. In this paper, in addition to loss reduction and voltage profile improvement, reducing the fault current of the network lines to less than the rated fault current of the power switches is added as a third objective function to the optimization problem and the three objective functions are investigated simultaneously.

Using the Pareto optimal method to reach multiple optimal solutions, instead of a single optimal solution, in solving the multi-objective optimization problem of this paper.

Using fuzzy logic to find the most optimal possible answer from the set of optimal answers obtained from the Pareto front method.

The problem of microgrid energy management, along with its reconfiguration to determine the best network structure, is a complex nonlinear and non-convex problem that requires a suitable optimization algorithm to solve. Here, the combination of the WOA algorithm and the fuzzy technique, according to the results obtained, indicates the good efficiency of the method proposed in the paper.

3. Materials and Methods

Reconfiguration, placement and capacity determination of distributed generation and planning to determine the best grid structure is a complex nonlinear and non-convex problem that requires a suitable optimization algorithm to solve. In this paper, a combination of the WOA and fuzzy technique has been used to solve the multi-objective optimization problem. MATLAB software was also used to solve the issue. To investigate the effectiveness of the proposed approach, studies have been conducted on an IEEE 33-bus grid.

4. Results and Discussion

In the results section, three objective functions of reducing losses, improving the voltage profile, and reducing the fault current to an amount less than the rated current of the power switches are considered simultaneously. By performing simulation, the Pareto optimal solution set obtained with the proposed algorithm is shown in Figure 1. Fuzzy decision making showed a response that has characteristics according to Table 1. Also, the voltage curve of the grid buses is as shown in Figure 2.

Table 1. Results of implementing the fuzzy technique on the solution set for scenario 5

Location	Capacity (MW)	Open keys number	OF_1	OF_2	OF_3
8,33,24	1,1,0.8	5,13,15,25,21	66.38	0.0011	18.9941

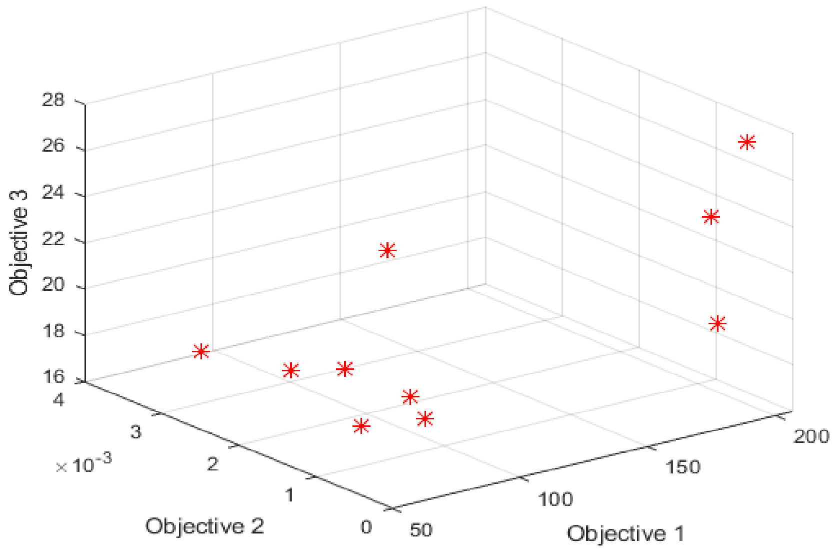

Figure 1. Pareto optimal solution set with the proposed algorithm for scenario 5

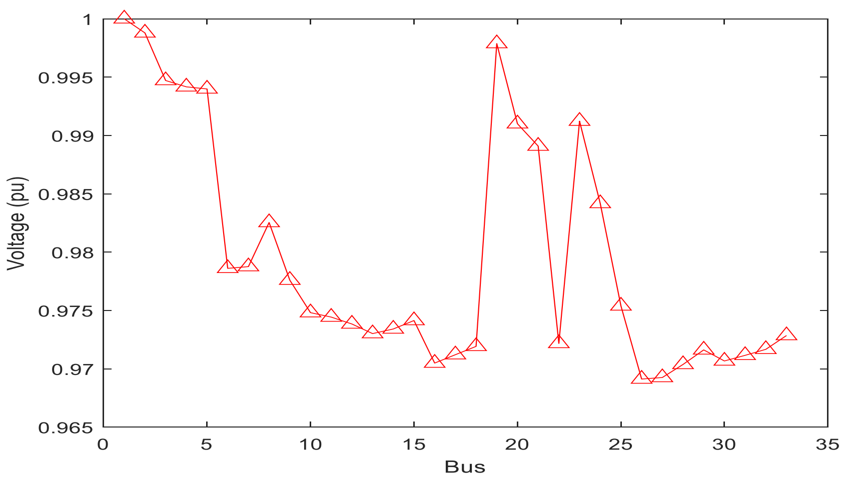

Figure 2. Voltage magnitude of grid buses for scenario 5

5. Conclusion

In this paper, a multi-objective optimization algorithm is used to solve the distribution network reconfiguration problem considering microturbines as one of the distributed generation sources. The objectives include reducing losses, improving the voltage profile, and reducing the fault current of the network lines to less than the rated fault current of the power switches in the presence of microturbines, which is performed as a multi-objective reconfiguration simultaneously. The optimal switch positions are obtained using the proposed WOA algorithm to reduce the line fault current to less than the rated fault current of the power switches, minimize power losses, and improve the voltage profile. Then, fuzzy logic technique is used to select the best grid structure. The proposed method is implemented on a 33-bus IEEE distribution grid. If, in addition to reducing losses and improving the voltage profile, the optimal location and capacity of microturbines, as well as the fact that the fault current of the network lines is less than the tolerable current of the power switches, are considered as three simultaneous goals, the results obtained indicate the good efficiency of the method proposed in this paper.

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7. References

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Appendix

Table 1. Results of implementing the fuzzy technique on the solution set for scenario 2

Location	Capacity (MW)	OF_1	OF_2
30-16-24	1-1-1	80.0568	0.000343

Table 2. Results of implementing the fuzzy technique on the solution set for scenario 3

Optimal keys number	OF_1	OF_2
7,13,21,36,37	157.6518	0.007

Table 3. Results of implementing the fuzzy technique on the solution set for scenario 4

Location	Capacity (MW)	Open keys number	OF_1	OF_2
9,25,33	0.8,1,1	7,10,12,16,28	62.1932	0.0003206

Table 4. Results of implementing the fuzzy technique on the solution set for scenario 5

Location	Capacity (MW)	Open keys number	OF_1	OF_2	OF_3
8,33,24	1,1,0.8	5,13,15,25,21	66.38	0.0011	18.9941

Table 5. Results of multi-objective optimization problem using PSO algorithm

Location	Capacity (MW)	Open keys number	OF_1	OF_2	OF_3
30,16,24	1,1,1	7,13,10,25,31	89.04	0.0074	23.2981

Declaration of Competing Interest: Authors do not have conflict of interest. The content of the paper is approved by the authors.

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