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Multi-objective quasi-oppositional teaching learning based optimization for optimal location of distributed generator in radial distribution systems

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ABSTRACT

This paper presents a novel quasi-oppositional teaching learning based optimization (QOTLBO) methodology in order to find the optimal location of distributed generator to simultaneously optimize power loss, voltage stability index and voltage deviation of radial distribution network. The basic disadvantage of the original teaching learning based optimization (TLBO) algorithm is that it gives a near optimal solution rather than an optimal one in a limited iteration cycles. In this paper, opposition based learning (OBL) and quasi OBL concepts are introduced in original TLBO algorithm for improving the convergence speed and simulation results of TLBO. In order to show the effectiveness and superiority, the proposed algorithms are tested on 33-bus, 69-bus and 118-bus radial distribution networks. The simulation results of the proposed methods are compared with those obtained by other artificial intelligence techniques like GA/PSO, GA, PSO and loss sensitivity factor simulated annealing (LSFSA). The results show that the QOTLBO surpasses the other techniques in terms of solution quality.

Introduction

Nowadays, with the increased loading and exploitation of the existing power structure, the probability of occurrence of voltage collapse is significantly greater than before and the identification of the nodes which are prone to the voltage fluctuation have attracted more attention for the distribution systems. Presently, the distributed generation (DG) is gaining greater commercial and technical importance across the globe due to limited sources of fossil fuels used in conventional power plants. DG is generally connected close to the loads; it can increase the power quality and reliability from the customer's perspective and help the utilities to face the load growth delaying and the up gradation of distribution lines. In addition, the system losses should also be considered as an objective for economic operation of radial distribution network. Traditionally, capacitor and DG are installed in power networks to compensate for power loss reduction, voltage profile improvement and voltage stability enhancement. Among these devices, DG is most widely used in distribution network because it has a unique property of supplying active as well as reactive power, whereas capacitor supplies only reactive power to the network. Also, the disadvantages of capacitor placement in such system is that it cannot use renewable resources such as hydro, wind, solar, geothermal, biomass and ocean energy, which are naturally scattered around the country and also are smaller in size. Recently, these resources are tapped through integration to the distribution system by means of DG. Some of the major advantages in installing DG units in distribution level are peak load saving, enhanced system security and reliability, improved voltage stability, grid strengthening, reduction in the on-peak operating cost, reduction of network loss etc. [1]. Studies have indicated that there are different methods used for the location and size of DG. Therefore, the optimal location and size of DG is an important task for the researchers.

Acharya et al. proposed loss sensitivity factor method [2] for minimizing the total power losses in primary distribution systems. A mixed integer linear program (MILP) was formulated by Keane and O'Malley [3] to determine the DG plant mix on a network section. However, it requires the conversion of the power system approximately as a linear system, which is not a real case. Borghetti proposed (MILP) model [4] to minimize system real power loss of radial distribution network. Franco et al. also proposed MILP [5] approach to solve optimal DG allocation problem at different load levels for radial distribution network. But it is a robust and repeatable method. The requirement to pre-specify locations is the major issue with this approach. It requires a pre specified capacity or location. This method does not scale well to

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higher dimensional problems. Nowadays, power networks have become more complex due to increasing load demand. This situation resulted into voltage stability problem. A number of analytical and computational tools were discussed [6,7] for accurate analysis of voltage stability. The sensitivity factor based on equivalent current injection was employed in [8] for the determination of the optimum size and location of DG to minimize total power losses of radial systems. Caisheng presented analytical approaches [9] to solve optimal DG allocation problem. Ramana et al. presented variational algorithm [10] to place DG in optimal location for minimizing power loss and improving voltage stability of three phase unbalanced radial distribution system. Khan et al. presented an analytical approach [11] to improve voltage profile and minimize power losses of radial distribution network. The simulation results indicated that the proposed algorithm was capable of identifying the optimal location and size of DG in distribution system effectively. However, this analytical study is based on phasor current injection method which has unrealistic assumptions such as uniformly, increasingly, centrally distributed load profiles. These assumptions may cause erroneous solution for the real systems. Recently Naik et al. introduced analytical method [12] for optimal allocation of DG and capacitor to minimize total real power loss subjected to equality and inequality constraints in the distribution network. Mametic algorithm used by Sayyid et al. [13] for placement of capacitor and DG in radial distribution network for the reduction of active and reactive power loss, energy loss and improvement of voltage profile. Rezaei et al. used dynamic programming (DP) technique [14] to place DG in distribution system to minimize power loss, improve reliability and voltage profile of the system. Aman et al. presented power stability index (PSI) [15] to visualize the impact of DG on system losses, voltage profile and voltage stability. The proposed method was implemented on 12-bus, modified 12-bus and 69-bus systems and its performance was compared with golden section search (GSS) algorithm.

Despite the fact that some of the above mentioned techniques have excellent convergence characteristics for solving linear optimization problem, some of their drawbacks are: The performances of these techniques are highly dependent on the initial guess, i.e. they might converge to local solutions instead of global ones if the initial guess happens to be in the vicinity of a local solution. Moreover, they are developed with some theoretical assumptions, such as convexity, differentiability, and continuity, which may not be suitable for the practical non-linear and non-differentiable optimization problem. Since, DG placement in distribution system is a discrete non-linear optimization problem, the classical methods mentioned above have failed to obtain optimum solutions. It is therefore essential to develop new, robust and reliable algorithms, which are capable of handling discrete non-linear optimization problem.

Recently, many stochastic search algorithms have been developed and successfully implemented to solve optimal DG placement problem. Vankatesh et al. proposed evolutionary programming (EP) [16] for optimal reconfiguration of radial distribution system to maximize loadability index. Genetic algorithm (GA) based DG placement techniques used to reduce overall power losses in a distribution system was presented in [17]. Popvic et al. proposed GA [18] for optimal sitting and sizing of DG in distribution systems. Carmen et al. [19] used a modified GA for determining the optimal size and location of DG in distribution systems, in order to minimize the electrical network losses and improve reliability level and voltage profile. A hybrid GA-OPF method [20] was proposed by Harrison et al. to determine the optimal number of deployed DGs in the distribution networks. A fuzzy embedded GA [21] for optimal placement of DG was introduced by Vinothkumar and Selvan. A dual GA (DGA) based approach [22] was implemented by Yang et al. to improve power quality and voltage deviations of radial systems. Lopez-Lezama et al. presented modified GA [23] to determine the location and contract pricing of dispatchable DG units in distribution systems. A dynamic approach based on modified GA was proposed in [24] to minimize capital, operation, maintenance costs and cost of losses. However, the problem with GA is that it is computationally intensive and suffers from excessive convergence time and premature convergence.

A binary coded PSO based stochastic dynamic multi-objective model [25] for integrating DG in distribution networks was proposed by Soroudi and Afrasiab. A modified discrete PSO [26] for planning of distribution networks considering DG and cross-connections (CC) to improve system reliability and to minimize line losses under load growth was introduced by Ziari et al. A multi-objective PSO (MOPSO) was developed in [27] to determine the optimal number, location and size of DG unit in distribution system. A hybrid method which employed discrete PSO and optimal power flow (OPF) was introduced in [28] to connect DG in a distribution network choosing among a large number of potential combinations. Moradi et al. proposed combined GA and PSO technique (GA/PSO) [29] for optimal location and sizing of DG in a distribution system in order to improve voltage regulation, voltage stability and to minimize network power losses of 33-bus and 69-bus systems. Recently, Khyati et al. proposed PSO technique [30] to determine the optimum size and location of multiple DGs to provide the incremental load on the system and to minimize power loss which was applied to IEEE standard 33-node system. To identify the optimal location and size of DG and power stability index PSO algorithm [31] was used. An artificial bee colony (ABC) [32] algorithm to determine the optimal DG size and location in order to minimize the total power loss was proposed by Abu-Mouti et al. The proposed method was tested on IEEE 33 bus system. An optimal DG allocation based ACO algorithm to find the reliability index of radial distribution system was proposed by Wang et al. [33]. Kumar et al. used price area zonal based method [34] to obtain optimal location and size of DG. A market-simulation based method was presented in [35] to study the impacts of DGs on transmission-expansion planning. Hengsritawat et al. presented a probabilistic approach [36] to design an optimal size of photovoltaic DG (PV-DG) in a distribution system. The objective of proposed technique was to minimize the average system active power losses, while considering power quality constraints. The proposed technique was tested on an actual 51 bus medium voltage distribution system in Thailand. Nayak et al. applied differential evolution (DE) [37] for optimal placement of DG on IEEE-69 bus radial system to minimize the total real power loss and improve the voltage profile. Kumar et al. proposed loss sensitivity factor simulated annealing (LSFSA) method [38] for optimal placement and sizing of DG in a large scale distribution system to minimize network power losses and to improve voltage stability. The proposed method was tested on 33-bus, 69-bus and 118-bus systems and the results were compared with the results of GA, PSO and GA/PSO. An improved multi-objective harmony search (IMOHS) algorithm [39] to determine the optimal DG size and location in order to minimize total power loss and voltage profile was introduced by Nekooei et al. A multi-objective optimal DG placement based hybrid modified shuffled frog leaping algorithm (SFLA) to minimize total energy losses, energy cost and emissions was proposed by Mojarrad et al. [40]. Improved tabu search (TS) algorithm [41] to minimize loss in large-scale distribution systems was proposed by Zhang et al. Mohammadi et al. proposed GA-based TS method (GATS) [42] to solve optimal DG allocation problem of restructured distribution system. Continuation of power flow analysis [43] for placement of DG units was proposed by Hedayati et al. A feed forward artificial neural network (ANN) [44] to determine appropriate location and size of DG was proposed by Kayal et al. The proposed method was tested on 52-bus system.