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Quasi-Oppositional Swine Influenza Model Based Optimization with Quarantine for optimal allocation of DG in radial distribution network

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ABSTRACT

Optimal allocation of Distributed Generations (DGs) is one of the major problems of distribution utilities. Optimum locations and sizes of DG sources have profoundly created impact on system losses, voltage profile, and voltage stability of a distribution network. In this paper Quasi-Oppositional Swine Influenza Model Based Optimization with Quarantine (QOSIMBO-Q) has been applied to solve a multi-objective function for optimal allocation and sizing of DGs in distribution systems. The objective is to minimize network power losses, achieve better voltage regulation and improve the voltage stability within the frame-work of the system operation and security constraints in radial distribution systems. The limitation of SIMBO-Q algorithm is that it takes large number of iterations to obtain optimum solution in large scale real systems. To overcome this limitation and to improve computational efficiency, quasi-opposition based learning (QOBL) concept is introduced in basic SIMBO-Q algorithm. The proposed QOSIMBO-Q algorithm has been applied to 33-bus and 69-bus radial distribution systems and results are compared with other evolutionary techniques like Genetic Algorithm (GA), Particle Swarm Optimization (PSO), combined GA/PSO, Teaching Learning Based Optimization (TLBO) and Quasi-Oppositional Teaching Learning Based Optimization (QOTLBO). Numerical studies represent the effectiveness and out-performance of the proposed QOSIMBO-Q algorithm.

Introduction

Electric utilities are continuously planning the expansion of their existing electrical networks to meet the increasing load growth. The traditional solution is the construction of new substation or the expansion of those already exists. However, these companies began to evaluate new alternatives of expanding their capacities when government started to simulate the addition of new power sources to the system [1–3]. An alternative way to satisfy the increasing demand is to use Distributed Generation (DG) system. Distributed Generation can be defined as small scale generation which is located onsite or close to the load centre and is interconnected to the distribution network. Some advantages of DG are grid reinforcement, power loss reduction, increasing efficiency, eliminating the upgrades of power system, reliability, improving voltage profile and load factors and hence power quality, reducing transmission and distribution costs, saving the fossil fuel, decreasing in electricity price, reduction in emissions of green-house gases and also sound pollutions. Presently a number of DG technologies available in the market and few are still under research and development stage. Different DG technologies are reciprocating engines, combustion gas turbines, micro turbines, fuel cells, photovoltaic system, wind turbines, small hydro-electric plant, etc.

One of the important aspects of DG research study is related to its proper placement at strategic points of power systems to minimize the losses of power system, improving the voltage profile, reliability, maximizing DG capacity, cost minimization, etc. Selection of the best places for installation of DG units and their preferable sizes is possible by using an appropriate optimization method which can provide the best solution for a given distribution network [3].

Many researchers proposed different methods such as analytical methods as well as deterministic and heuristic methods to solve optimal DG placement and sizing problem. Authors Frauk Ugranli and Engin Karatepe [4] proposed a power flow algorithm based on Newton–Raphson method to consider the impact of multiple DG units on power losses and voltage profile in respect of point of

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common coupling (PCC), DG size and power factor of DG. Elnashar et al. [5] presented a visual optimization approach for determining the optimal placement and sizing of the DG through the choice of the appropriate weight factors of the parameters like losses, voltage profile and short circuit level. Ghosh et al. [6] suggested a simple conventional iterative search technique based on Newton–Raphson load flow method study for optimal sizing and placement of DG by optimizing both cost and loss simultaneously. Singh and Goswami [7] presented a new methodology based on nodal pricing for optimally allocating DG for profit maximization, loss reduction and voltage improvement including voltage rise phenomenon. Gozel and Hocaoglu [8] proposed an analytical method based on loss sensitivity factor for optimal size and location of DG in radial systems to minimize the power losses. The proposed method was based on equivalent current injection that uses the bus-injection to branch current (BIBC) and branch-current to bus-voltage (BCBV) matrices developed on the basis of the topological structure of the distribution systems. Acharya et al. [9] presented an analytical approach which is based on the exact loss formula to calculate the optimal size and location of DG for minimizing the total power losses in primary distribution systems. Authors of [10–12] also applied analytical methods for solving DG sizing and placement problems. Kazemi and Sadeghi [13] presented a load flow based algorithm for DG allocation in radial systems for voltage profile improvement and loss minimization. Moradi et al. [14] presented a Genetic Algorithm (GA) based evolutionary technique for optimum placement and sizing of four different types of DG and the objective was to minimize real power loss within security and operational constraints. Alibadi et al. [15] proposed a combination of GA and optimum power flow (OPF) technique for optimum placement and sizing of DG units in a given distribution system to minimize the cost of active and reactive power generation. Gomez-Gonzalez et al. [16] applied a new discrete Particle Swarm Optimization (PSO) and OPF technique to achieve optimal location and size of DG system in a distribution system. Moradi and Abedini [17] proposed a combined GA/PSO technique for finding optimal location and sizing of DG to minimize the losses, to increase the voltage stability and to improve the voltage regulation index within the framework of the system operation and security constraints in radial distribution systems. Sultana and Roy [18] presented a quasi-oppositional teaching learning based optimization (QOTLBO) to find optimal location of DG units to minimize power loss and voltage deviation, and to improve the voltage stability index of radial distribution network. Moradi et al. [19] presented a multi-objective Pareto Frontier Differential Evolution (PFDE) algorithm to determine optimal location and size of multiple DG sources for loss minimization, voltage profile and voltage stability improvement of 33 bus and 69 bus radial distribution systems. Esmaili et al. [20] applied dynamic programming search method for locating and sizing of DGs in distribution network to enhance voltage stability and to reduce network losses simultaneously by maintaining voltage security limits. Ishak et al. [21] determined optimal DG location and size through a novel maximum power stability index (MPSI) with PSO to improve power system stability and to reduce system active power losses. Aman et al. [22] presented a new approach based on maximization of system loadability to determine optimum placement and sizing of multi-DG using Hybrid PSO (HPSO) algorithm. The aim was to minimize system loss, maximize system loadability and to improve voltage quality. Devi and Geethanjali [23] proposed Modified Bacterial Foraging Optimization (MBFO) algorithm for optimal allocation of DG to reduce the total power loss and to improve the voltage profile of radial distribution systems. In [24] Attia El-Fergany presented Backtracking Search Optimization Algorithm (BSOA) to determine optimal allocation of multi-type DG in radial distribution network to reduce the network real power loss and to enhance the voltage profile. Mohandas et al. [25] presented Chaotic Artificial Bee Colony (CABC) algorithm for optimal allocation of real power DG units for enhancing the voltage stability of radial distribution system using multi-objective performance index (MOPI). In [26,27], authors applied ant colony optimization and dynamic programming approach for solving DG sizing and placement problems.

In this paper a new population based optimization technique known as Quasi-Oppositional Swine Influenza Model based Optimization with Quarantine (QOSIMBO-Q) has been applied to solve the optimal allocation problem of DG in radial distribution systems. Swine Influenza Model based Optimization (SIMBO) was developed by Pattnaik et al. [28] and it is mimicked from Sus ceptible-Infectious-Recovered (SIR) models of swine flu. The developments of SIMBO follow through treatment (SIMBO-T), vaccination (SIMBO-V) and quarantine (SIMBO-Q) based on probability. The SIMBO variants are used to solve complex multimodal problems with fast convergence and also delivering good quality of optima. SIMBO algorithms do not require more computational effort to achieve the optimum value. The algorithm converges rapidly due to the presence of vaccination/quarantine and treatment loops. The major advantages of SIMBO variants are their easy implementation and better accuracy to reach to the optimum solution. Exploration and exploitation ability of SIMBO is much improved compared to many previously developed optimization techniques. It has been observed that the performance of SIMBO-Q is quite satisfactory compared to many other optimization techniques like GA, PSO, combined GA/PSO, TLBO and QOTLBO. However for applying SIMBO-Q algorithm in large scale real system, large number of iterations may be required to obtain optimum solution. As a result the convergence rate becomes slower for large scale optimization problem. Therefore to improve the solution quality and to accelerate the convergence speed quasi-opposition based learning (QOBL) concept has been incorporated to basic SIMBO-Q algorithm. In this paper the authors have proposed Quasi-Oppositional Swine Influenza Model based Optimization with Quarantine (QOSIMBO-Q) to evaluate optimum location and size of multiple DG to minimize active power loss, to improve voltage profile and voltage stability of 33 bus and 69 bus radial distribution networks. To show the effectiveness and superiority, the results obtained with QOSIMBO-Q algorithm is compared with many other popular optimization techniques.

The paper is structured as follows: Section "Problem formulation" of the paper provides a brief description and mathematical formulation of power loss minimization, voltage profile improvement and voltage stability improvement problems for optimal placement and sizing of DG. Section "Optimal placement and sizing of DG using QOSIMBO-Q algorithm" describes optimal placement and sizing of DG using QOSIMBO-Q algorithm. Simulation results and discussion are presented in Section "Simulation results and discussion". The conclusion is drawn in Section "Conclusion".

Problem formulation

Proposed methodology in this paper aims to find optimum placement and size of DGs in a given radial distribution system by minimizing the power losses, maximizing the voltage stability and improving voltage profile in a radial distribution network. The full formulation of the DG optimization problem is organized in the following sections.

Case 1: Active power loss minimization

The objective function to minimize real power loss of the distribution system is given by:

$$f_1 = Min(P_{RPL}) \tag{1}$$