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OPTIMIZATION IN DISTRIBUTED GENERATION USING RENEWABLE ENERGY RESOURCES - REVIEW

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Abstract

This paper mainly deals with the potential benefits to the quality and reliability of delivered power can be attained with the installation of distributed generation units. To take full advantage of these benefits, it is essential to place optimally sized distributed generation units at appropriate locations. Otherwise, their installation could provoke negative effects to power quality and system operation. Over the years, various powerful optimization tools were developed for optimal integration of distributed generation. Therefore, optimization techniques are continuously evolving and have been recently the focus of many new studies. This paper reviews recent optimization methods applied to solve the problem of placement and sizing of distributed generation units from renewable energy sources based on a classification of the most recent and highly cited papers. In addition, this paper analyses the environmental, economic, technological, technical, and regulatory drivers that have led to the growing interest on distributed generation integration in combination with an overview about the challenges to overcome. Finally, it examines all significant methods applying optimization techniques of the integration of distributed generation from renewable energy sources.

Introduction

The development of Distributed Generations (DG) throughout the world is presented in two levels, with Research & Development (R&D) advancements and the expansion of DG projects. On the research side, Fig.1 shows the rapid increase witnessed during the last decade in the number of research papers that use optimization methods in the DGs deployment from RES using Scopus database2. Accompanying the evolution in research papers, there has been also a growth in DG installations. For instance, the liberalization of power market in Europe fostered the development of DGs with about 40% penetration in Denmark and Netherlands [1].

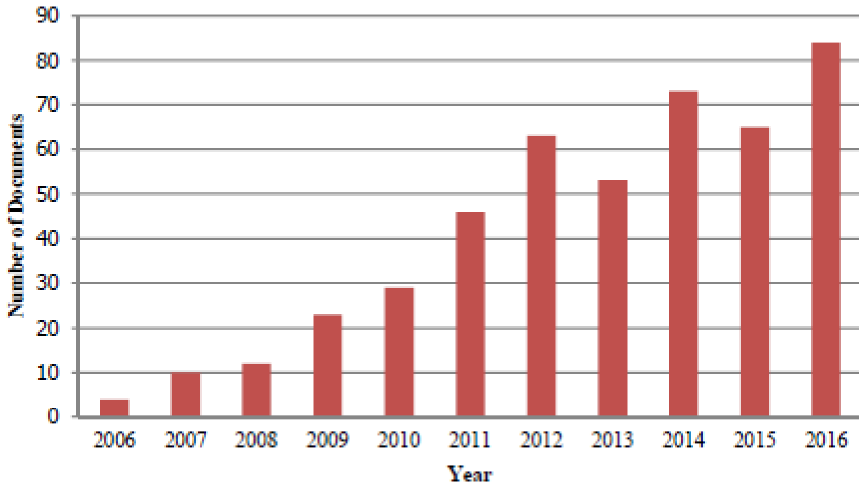

Fig 1 Number of articles using optimization methods applied in the deployment of DGs from RES in the past 10 years

This rising interest in the use of optimization methods applied for the deployment of DGs from RES is expanded all over the world with more than half of the total research papers produced from developed countries such as European countries (Italy represents ¼ of the total European countries), USA, and Japan. However, about 30% of the total research papers are produced by emerging developing economies such as China, Iran and India. The interest in the developed countries and the highest emerging developing countries can be explained by the international pressure on the reduction of CO_2 emissions and the encouraging policies and incentives regarding the use of RES. In addition, it is noticeable that more interest is starting to grow even in countries rich in fossil fuels, such as Saudi Arabia and UAE. This is manifested with their decision to consider RES as a viable alternative to conventional sources of energy in order to meet their fast-growing domestic demand, ensure national security, and diversify their economies.

Despite the various benefits resulting from the deployment of DGs from RES, studies have indicated that utilities may face new challenges of increased system losses caused mainly by inappropriate selection of location and size of DGs [2]. By including optimization techniques, utilities will be able to address the problems of losses, reliability and quality of the supplied electricity. Additionally, optimal placement of DGs can further reduce the need for new time-consuming and costly investments, and save investments related to the Transmission and Distribution (T&D) systems [3]. In fact, T&D cost represents the biggest part of the capital budget for utilities (almost two thirds). Recently, the T&D cost has raised from 25% to around 150% of the generation cost [2]. Due to the recent concerns on environmental and increased cost of T&D, large central power plants become often ineffective. This paper shed light on the diverse existing optimization methods applied to the planning and integration of DG from RES. The focus is on solving the problem of placement and sizing of DG units. A summary grouping all the discussed optimization methods provided at the end will help to choose the most effective technique to model a similar problem and solve it.

DG Growth

In this section, a summary focusing on DGs from RES in India. This analysis will emphasize on the actual context of the transition into a more active management of power systems and smart grid application. An overview about the challenges to overcome will be presented as well.

In the past ten years, installation of renewable energy for electricity has grown at an annual rate of 25%. It has reached 30,000 MW as of January 2014. During this period, wind power installation has grown ten times and solar energy has grown from nothing to 2,500 MW. Currently, renewable energy accounts for about 12% of the total electricity generation capacity and contributes about 6% of the electricity produced in the country. Renewables, therefore, produce more than twice the amount of electricity produced by all nuclear power plants in the country. In 2012-13, the electricity produced by renewables was equivalent to meeting the per capita annual electricity requirement of about 60 million people. More than a million households in the country, today, depend solely on solar energy for their basic electricity needs.The growth of renewable energy has changed the energy business in India. It has, in many ways, democratised energy production and consumption in the country. Before the renewable sector became a significant player, the energy business was all about fossil fuel-based big companies and grid-connected power—they dominate even today. But today there is an alternate energy market in which thousands of small companies and social businesses are involved in selling renewable energy products and generating and distributing renewables-based energy. This trend is likely to accelerate because of two key policies of the government.

The first is the Electricity Act, 2003. The Act has opened up the rural electrification market to decentralised distributed generation systems. It promotes decentralised generation and distribution of electricity involving institutions like the panchayats, users' associations and cooperative societies in rural India not under the purview of distribution companies. In addition, private developers are free to set up renewable energy based generators and sell electricity to rural consumers. The second impetus to decentralized renewables comes from rooftop solar policies of state governments. States like Gujarat, Andhra Pradesh, Uttarakhand, Karnataka, and Tamil Nadu have policies to promote solar energy generation from rooftops of residential, commercial and industrial buildings. The response to these policies has been highly encouraging. Although the results of this policy are likely to be realized slowly, the stage for re-inventing electricity generation with power from rooftop installations has been set. Hence the main drivers behind the expansion of DGs from RES can be categorized into five main classes: environmental, economic, technological, technical and regulatory drivers. In fact, DG has a direct effect on power flow and voltage quality, which is generally described as "system support benefits", and includes:

- Voltage support and power quality enhancement;
- Loss decrease;
- Capacity relief at T&D levels;
- System reliability;
- Peak load shaving and reliability enhancement;
- Flexibility to track load variation;
- Backup supply in case of sudden contingencies.

Challenges

Despite the numerous benefits and drivers behind the expansion of DGs, economic and technical challenges can result from the aggressive integration of DGs. Some of the major problems facing DGs are outlined here. First of all, with DGs power flow has changed from unidirectional into bidirectional flow within a certain voltage level. Thus, an aggressive integration of DG units may affect the grid stability and power system quality. Accordingly, the choice of the installed DG capacity will not only depend on the cost and benefits of each technology, but also will depend on the optimal location and size that enable high loss reduction in the overall system [4]. In addition, the structure of the electricity market is one of the challenges facing DGs installation. In fact, in a traditional non-liberalized power system, the market is usually characterized by a vertically integrated monopoly. However, in a liberalized market, risk investments in DGs are leveled through the competitiveness created by new opportunities.

Optimization Approaches For Dgs Placing And Sizing

Uncertainties and variability are the main challenges associated with RES, especially with non-continuous availability of wind, solar and hydro resources. To accommodate the integration of large share of RES, it is important to have appropriate planning tools able to optimize the integration of variable RES. Many optimization techniques related to energy problems in general exist in the literature, such as conventional and intelligent search methods. In principal, searching for the optimal site and capacity of DG is usually modelled as a non-linear mathematical optimization problem. Various constraints and objective functions are first set. The optimization technique help in decision-making by generating one optimal or a set of optimal solutions or output variable from a reduced set of initial input variables. Broadly, there are two approaches to solve a problem, by exact methods such as Mixed-Integer Linear Programming (MILP) which is usually very effective but necessitate excessive computing time and hard to implement on real size problems, and heuristic methods which is based on simplifying the problem and offering satisfying solutions. In this section, a simple formulation of the most common problem is presented, which is to find the optimal DG size and bus location that minimize the network total losses. The resulting objective function is minimized in the presence of suitable equality and inequality constraints. Prior to introducing the mathematical model, some notation is provided.

1. **Parameters**

N: The set of all branches
R_{ij}: resistance between bus i and bus j
V_i, V_j: voltage magnitude at bus i and bus j respectively
θ_i, θ_j: voltage angle at bus i and bus j respectively
V^{min} : Minimum Voltage bound
V^{max} : Maximum Voltage bound
P_{DG}^{min} : Minimum active power output
P_{DG}^{max} : Minimum active power output

The Decision variables as follows:

P_i, Q_i: active and reactive power injection at bus i
P_j, Q_j: active and reactive power injection at bus j

Based on the exact formula of total losses developed by Elgerd [18], the objective function requires the minimization of the total power losses. That is,

$$Minimize(P_{loss}\{DG(i, size)\}) \quad \text{----- (1)}$$

$$P_{loss} = \sum_{i=1}^{N}\sum_{j=1}^{N}[\alpha_{ij}(P_iP_j + Q_iQ_j)] \quad \text{----- (2)}$$

where the coefficients α_{ij} and β_{ij} are determined as

$$\alpha_{ij} = \frac{R_{ij}}{V_iV_j}\cos(\theta_i - \theta_j) \;, \qquad \beta_{ij} = \frac{R_{ij}}{V_iV_j}\sin(\theta_i - \theta_j), \quad \text{----- (3)}$$

where $R_{ij} + jx_{ij} = Z_{ij}$ is the ij[th] element of $[Z\,bus] = [Y\,bus]^{-1}$

Subject to

Power balance constraint H(x,u)=0
where x – is the vector of power system optimization variables.
u – is the control vector of the independent variables.

Normally the bus voltage $V_i \leq 1.05$PU. Voltage bounds are given by

$$V^{min} \leq V_i \leq V^{max} \quad \text{------ (4)}$$

DG real power output constraint is as follows:

$$P_{DG}^{\ min} \leq P_{DG} \leq P_{DG}^{\ max} \quad \text{----- (5)}$$

To solve these models, a large variety of optimization techniques were proposed in the literature so far. These methods can be generally classified as heuristic methods, analytical-based techniques, gradient and second order methods, and iterative methods. Heuristic methods may include Genetic Algorithms (GAs), Artificial Bee Colony Algorithm (ABCA), Tabu Search (TS) and Particle Swarm Optimization (PSO). These optimization methods have given acceptable results over the years, in addition to mathematical programming such as Linear Programming (LP) and Optimal Power Flow (OPF), are also widely presented in the literature. Considering the objective function, two categories of optimization methods can be presented, which are single-objective and multi objectives approaches. The most common objective found in this review is the minimization of the power system losses. In addition, other approaches focus on saving the total cost, which can be evaluated from different perspectives. In fact, the problem can be formulated from the perspective of a DER developer, or the perspective of Distribution System Operator (DSO) that want or refuse to invest in DER [5]. Actually, multiple objectives of an optimization problem create naturally a certain conflict, where no single solution is able to satisfy all the different perspectives. For example, in a DG placement and sizing problem, the objective function of maximizing DG capacity can create a conflict with not only the increase of line losses, but also with the potential increase in investments cost as well as society's interest to reduce CO2 emissions [6]. In general, multi-objective optimization problems contain various objective functions that need to be simultaneously minimized or maximized [7]. One of the most common available approaches to solve multi-objective optimization problems is the so-called weighted sum approach which consists in converting the multi-objective problem into a single-objective problem using pre-specified weights. Despite the simplicity of the weighted sum approach, there are some disadvantages associated with it. On one hand, weighted sum approach cannot be applicable to non-convex problems [8] and dissimilar objectives cannot be added together. On the other hand, the proposed solution is only applicable for the set of weights (priorities) chosen for the objective functions. It enumerates all possible types of constraints and objective functions related to the allocation and sizing problem of DGs.

2. Conventional methods

In this section, some conventional optimization methods are reviewed to solve the problem of DGs allocation and sizing. In fact, during the recent years the interest in using analytical approaches to handle optimization problem has grown greatly [9] in addition to traditional methods such as methods based on Linear Programming.

Analytical approaches

Analytical approaches usually produce a numerical equation that can be examined for optimization. The accuracy of the method highly depends on the model developed. It might also be applied in combination with another model based on the simulation results of the system. However, they are mostly based on theoretical, calculations, and mathematical analysis. They offer the advantage of short computing time and easiness in implementation while ensuring convergence of the problem. Nevertheless, the assumptions used for simplifying the problem may threaten the accuracy of the solution when the problem becomes complex. For instance in [10], the applied analytical method was based on the analysis of continuous power flow calculations and identification of the buses that are most susceptible to voltage drop. This approach proved to be successful in improving voltage profile and reducing power losses while increasing power transfer capacity. Moreover, some new analytical approaches were based on Power Stability Index (PSI) in order to illustrate the impact of DG on the power system. PSI analytical approach was tested in [11] on several types of buses in radial distribution networks.

Linear and Non-Linear Programming (LP & NLP)

LP is a type of mathematical programming utilized to solve a mathematical model where the requirements are represented by linear relationships for maximizing or minimizing the objective function. One of the methods to solve LP problems is the simplex method that it is based on polytope edges of the visualization solid to determine the optimal solution [12]. LP is widely used in power system optimization problem as it gives the exact solution, such as finding the optimal size of DG units. In [13] LP was implemented to improve the effect of DG reactive power demand on the system voltages and increase the number of connected DGs while respecting the distribution voltage limits However, the mathematical model to solve is called Mixed Integer Nonlinear Programming (MINLP) when the variables are continuous and discrete and the objective function and constraints are non-linear (such as with power balance and cost equations. In the context of finding the optimal location and size of DGs in the power system, MINLP has been used in several papers [14], where the optimal locations of DGs were determined economically and operationally based on power loss sensitivity index. However, the very large number of decision variables and the long computation time are the major drawbacks of MINLP. There are many computing tools to solve LP and MILP problems, some of them are open source tools (like, COIN-OR) or commercial solvers (including CPLEX, GUROBI, XPRESS, LINDO, MATLAB to quote just a few).

Optimal Power Flow (OPF)

The goal of an OPF is to define the optimum economic operating cost to instantaneously operate a power system while considering the impact of the transmission and distribution systems. OPF was widely employed in the literature for solving DGs allocation and sizing problem since it considers already the economic aspect in the optimization problem [15]. For example "reverse load ability" approach was considered with OPF to maximize the size of DG and find available locations in the system considering the obligatory constraints underlined by the voltage and harmonics. In addition in [16] to solve the capacity allocation problem, switchgear was also considered as an additional fault level constraint imposed to protect equipment using an OPF model within limited numbers of contingencies (line outages).

Fuzzy Logic (FL)

Firstly, FL was introduced in 1979 as a generalization of classical set concept to solve problems related to power system. In fact, it consists on the identification of a membership function containing the level of association of each component by indicating a number between 0 and 1. This function measures the resemblance level of any element to a fuzzy subgroup. The most commonly utilized membership functions are the triangular, trapezoidal, piecewise-linear, and Gaussian functions. The number of memberships allowed is infinite [17]. FL is highly used in the allocation and sizing problem of DGs. For instance, in [18] FL was implemented to solve the optimal location problem of DGs aiming to minimize real power losses and enhance voltage profile.

3. Intelligent search methods

Artificial Intelligence is generally described as the exhibition of intelligence within machines [19]. Heuristic methods are considered as intelligent search methods, which consist on algorithms that speed up the process of

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finding a satisfactory or near optimal solution [20]. The major advantage of heuristic approach comparing to analytical approach is its simplicity. However, it sacrifices accuracy and precision. A meta-heuristic is an iterative process that can help to find near optimal solutions in a more efficient way [21]. The objective of meta-heuristics is to enlarge the aptitudes of heuristics by joining one or more heuristic methods [22]. The following sections present some of the most popular approaches, such as Genetic Algorithm (GA), Simulated Annealing (SA), Tabu Search (TS), Particle Swarm Optimization (PSO), Ant Colony Optimization (ACO), and Harmony Search (HS). Genetic algorithm was the first proposed method. Other methods that are based on natural evolution and animal social behaviors followed the GA. New methods such as HS were recently suggested which are based on different areas such as musical harmony.

Genetic Algorithm (GA)

GA is among the first developed heuristic methods since 1975 by Holland. It can be defined as a search technique based on the principles of genetics and natural selection, such as, selection, crossover, mutation, and inheritance [23]. Under a specified selection rules, GA permits for a population to evolve into a state that maximizes the “fitness” in contrast to other search techniques that work on a single solution. In fact, the population of elements is assimilated to chromosomes, which encrypts potential candidates, to evolve toward better state. Conventionally, solutions are represented in binary code. The first population is randomly generated and through evolution of generations, the suitability of every candidate is evaluated. The selected candidates are modified through mutation to form a new population. This will be repeated until the algorithm reaches a satisfactory level or maximum level of iterations. In the literature, GA is considered to be the most applied optimization techniques in solving the problem of DGs placing and sizing [24]. In [25] GA was applied in the aim to save the system expansion costs and increase the system reliability. As these two objectives are conflicting pareto-optimum models were used in order to determine the dominant solution at a single run. New enhanced methods are being proposed in the DG locating and sizing problem, such as in [66] where GA was combined with Multi-Attribute Decision Making (MADM) method considering different parameters of power system. Other enhanced methods of GAs can be listed such as Adaptive Genetic Algorithm (AGA) which has proved in [27] to be more robust and has greater search ability level, as well as Quantum Genetic Algorithm [28]. The major advantages and disadvantages that GAs face.

Advantages

- Have greater success at finding the global optimal to a wide variety of functions
- Do not require derivatives
- Can be applied with both discrete and continuous parameters
- Can be applied for complex and not well defined problems
- Bad solutions do not negatively affect the end solution

Disadvantages

- Can be time consuming for large and complex problems due to repeated fitness function evaluation
- Can suggest bad solutions
- Can be trapped into local optima
- Can be inaccurate

Simulated Annealing (SA)

SA is an iterative algorithm used to solve combinatorial optimization problems that exploits crystallization process in a physical system usually when the search space is discrete [29]. Originally, it was defined by S. Kirkpatrick, C. D. Gelatt and M. P. Vecchi in 1983, then by V. Černý in 1985. The cooling criterion is the core point of SA optimization method. In fact, SA depends on three variables: initial temperature (T), cooling rate (β), and final temperature (Tmin). The process is initiated with a feasible solution point. After system perturbation, new possible solutions will be determined based on a probabilistic acceptance criterion. In the literature, SA was used in [30] to locate and define the capacity of DGs while reducing computing time comparing to GA and TS methods. In addition, SA method is suitable for optimization problems which are based on stipulated reliability criteria. For example, in [31] power system planning based on reliability resulted into optimal size and location of DGs while meeting the consumer requirements with minimum system upgrade. The general advantages and disadvantages of SA method.

Advantages

- ❖ Can be simply implemented
- ❖ Can provide good solutions for many combinatorial problems
- ❖ Can be robust

Disadvantages

- ❖ May terminate in a local minimum
- ❖ Have large computing time
- ❖ Cannot provide information about the amount by which the local minimum deviates from the global minimum
- ❖ Local minimum can depend on the initial configuration (generally no guideline is available for the choice)
- ❖ Cannot give an upper bound for the computation time

Tabu Search (TS)

TS is a meta-heuristic approach that was firstly suggested by F. Glover in 1986 to solve optimization problems [32]. The approach is based on the principle of adaptive memory and responsive exploration that enable searching the solution space in an economic and effective way until no improvement is reached. TS was highly identified in solving the locating and sizing of DGs problem. For example in [33], Golshan et al. focused on DG optimal planning with the objective to minimize both losses and line loadings. However, TS has the disadvantage of large number of iterations and parameters to be determined. The main identified advantages and disadvantages of TS.

Advantages

- ❖ Can be used for complex problems
- ❖ Have explicit memory
- ❖ Can be applied to discrete and continuous variables
- ❖ Can be used for large problems

Disadvantages

- ❖ Can depend on the strategy for Tabu list manipulation
- ❖ Can get stuck in local minima
- ❖ Should determine many parameters
- ❖ Have many iterations
- ❖ Can depend on parameter settings to find global optimum

Particle Swarm Optimization (PSO)

PSO is an optimization approach developed by Eberhart and Kennedy in 1995. It is principally inspired from the social behavior of bird flocking and fish schooling (the particles are moving in a multidimensional search space, where single intersection of all dimensions forms a particle) [34]. The system is firstly adjusted with a set of arbitrary solutions and the optimization search is ensured through updating generations. At each iteration, the particles assess their positions considering their fitness level, while the neighboring particles show the history of their "best" positions in order to refine the final solution [35]. In DGs locating and sizing problem, PSO was extremely used in the literature [36]. For instance, in PSO is used to select the optimal location, type, and size of DG units to achieve the optimal integration of DGs taking into consideration harmonic limits and protection constraints. In addition, a PSO was employed in [37] to not only reduce Total Harmonic Distortion (THD), losses, and costs, but also improve the voltage profile. The results proved that PSO gave better solution quality and less number of iterations compared to GA method. In fact, PSO presents a shorter computational time in comparison with GA and can be adapted to real cases for power networks. New enhanced PSO methods are being proposed in the DG locating and sizing problem, such as Improved PSO (IPSO), Binary PSO (BPSO), Social Learning PSO (SLPSO), PSO with Inertia Weight (PSO-IW), and PSO with Constriction Factor (PSO-CF) [38]. The main advantages and disadvantages of PSO method are

Advantages

- Can be simple to implement
- Have few parameters to adjust
- Able to run parallel computation
- Can be robust
- Have higher probability and efficiency in finding the global optima
- Can converge fast
- Do not overlap and mutate
- Have short computational time
- Can be efficient for solving problems presenting difficulty to find accurate mathematical models

Disadvantages

- Can be difficult to define initial design parameters
- Cannot work out the problems of scattering
- Can converge prematurely and be trapped into a local minimum especially with complex problems

Ant Colony Optimization (ACO)

ACO algorithms were first published by Dorigo et al in 1996, which are principally inspired from the social behavior of insects (such as ants) in finding the shortest paths to get their food [39]. Physically, researcher discovered the existence of pheromone trails left by ants. This substance is used by other aunts in order to share the information about their path. Like other meta-heuristics, the process is initialized by random solutions which are assimilated to random searches performed by ants and the trails resulting from ants' movement. Consequently, the shorter the path, the more trails density increases. This information will be considered in the following searches. In [40] ACO is proposed to solve the location and size problem of DGs from RES in radial distribution systems while minimizing total system losses. The objective function used in [41] was based on a reliability index, where ACO algorithm was applied to solve discrete optimization problems. The results showed that ACO gave better solution quality and less computational time compared to GA. However, ACO presents longer time to converge since the solution space to be evaluated is larger, but still shorter than with analytical methods.

Advantages

- Can search among a population in parallel
- Can give rapid discovery of good solutions
- Can adapt to changes such as new distances
- Have guaranteed convergence

Disadvantages

- Probability distribution can change for each iteration
- Have a difficult theoretical analysis
- Have dependant sequences of random decisions
- Have more experimental than theoretical research
- Have uncertain time to convergence

Harmony Search (HS)

HS approach is a meta-heuristic optimization method which was developed relatively recently in 2001. Principally, HS is inspired by the technique used by musicians in order to improve the harmony of their instruments. Unlike other existing algorithms based on natural observed behaviors, HS is characterized by the musical performance process looking for a better harmony. HS was applied in [43] to find the optimal DG location in combination with loss sensitivity factor approach. In [44] it was concluded that deploying HS algorithm was more acceptable than PSO for DG allocation to ameliorate voltage stability. Some of the advantages of HS method are

Advantages

- ❖ No Initial value settings are required
- ❖ Can use discrete and continuous variables
- ❖ Cannot diverge
- ❖ may escape local optima

Disadvantages

- ❖ Ability to search for local is weak
- ❖ Can reach a high number of iterations
- ❖ May encounter unproductive iterations without improving the solution
- ❖ Have high dimensional multimodal problem

Further Heuristic Methods

Some authors implemented further heuristic methods efficient for solving the DGs locating and sizing problem appeared in recent years, such as:

- ***Artificial Bee Colony (ABC)*** which is an optimization algorithm inspired by the searching behavior of honey bee swarm. ABC algorithm was applied in [45], where the comparison of the method with PSO approach showed that ABC offered better quality of the solution and faster convergence.
- ***Cuckoo Search Algorithm (CSA)*** which is based on the obligate brood parasitism of some cuckoo species that is characterized by placing their eggs in the nests of other host species. CSA was implemented in [46] to enhance voltage profile and minimize power losses for DG biomass and solar-thermal DG units.
- ***Shuffled Frog Leaping Algorithm (SFLA)*** which is based on the behavior of frogs while they are searching for their food. SFLA has been successfully applied to DG allocation and sizing problem. For example, in [47] SFLA was applied in order to maximize the system voltage profile and reduces line losses. SFLA has the advantage to associate between the benefits of GA and PSO algorithms.
- ***Shuffled Bat Algorithm (SBA)*** which is inspired by the echolocation behavior of micro-bats. This proposed algorithm was tested in [48] on a radial distribution systems to demonstrate its effectiveness With 100% base load conditions at a first stage , then with 120%.
- ***Plant Growth Simulation Algorithm (PGSA)*** which mimics the growing process of plant phototropism. The principle of PGSA is based on the search of the feasible region as the plant grows in a certain environment. At each change of the objective function, the algorithm looks for the possibilities to grow a new branch on different nodes and then forms the complete model. In [49] PGSA was efficiently applied where the objective function was to decrease the losses and improve the voltage profile. The major advantage of PGSA is the capability to function without the need for external parameters.
- ***Biogeography Based Optimization (BBO)*** which is based on the mathematical models of biogeography. It describes several behaviors related to species like animals, fish, birds, or insects, such as their evolution, their migration between regions, and their extinction. This new approach was employed in [50] for the optimal allocation and sizing of capacitor banks and DGs under the objective of improving power quality and THD.
- ***Firefly Algorithm (FA)*** which is based on the signal transfer used between fireflies in a courtship system. In fact, the firefly's flash aims to act as a signal system to seduce other fireflies. In [51] the optimal allocation of DG was ensured by FA with the objective of minimizing real and reactive power losses and line loading.
- ***Imperialist Competitive Algorithm (ICA)*** which is a search strategy method based on socio-political science in order to solve optimization problems. Firstly, ICA starts with an initial random set of individuals of P countries. The selected best countries are named the imperialists and the rest are considered colonies of these imperialists. Then, based on each imperialist's power colonies are divided among imperialists in order to build initial empires. In [52] the determination of DG location and size was ensured by ICA while including sensitive loads through islanding mode of a distribution network.

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Conclusions

This paper explains the need for optimization techniques applied for efficient integration of DGs especially from RES. It presents the global context that encouraged both the development of RES and the decentralization of generation units through DGs. The exponential increase of research papers using optimization techniques to solve DGs placement and sizing problem shows the great interest towards this topic among power system researchers. This paper offers a review of the recent published works about the application of different optimization techniques to solve the optimal location and size of DG problem in power systems. It summarizes the several conventional optimization techniques used to address the problem, and classifies them taking into consideration their main advantages and limitations. The review provides also a survey of most recent works as essential guidelines for the future research and enhancement on optimal DG placement and sizing. It shows the variety of the existing optimization techniques especially with heuristic and metaheuristic methods

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