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Optimization Techniques and Algorithms for DG placement in Distribution System: A Review

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ABSTRACT: Distribution system reconfiguration and DG installation is a technique that reduces real and reactive power loss, improves voltage profile, enhance power system stability, security of the system and minimizes the cost of installed distributed generation (DG), green house emission. It also minimizes the operational expenses of the system, improves the service operating conditions under normal and abnormal cases. However, DG installation at non-optimal locations in the electrical distribution system will lead to undesirable impacts on system voltage variations and total power loss. Hence, an optimal strategy has to be developed for solving the optimal location and sizing of DG. In recent years several analytical, classical, meta-heuristic and intelligence techniques have been implemented for solving this problem. The main objective of optimal distributed generation placement (ODGP) is to obtain an optimal location and sizing of DG have to be installed subject to several constraints. The optimal position of the switches and the protective devices are the most significant aspects in planning electrical distribution systems. In a distribution system, switching devices play a crucial role in reconfiguration of network and DG installation. A complete review based on the recent works published in the network reconfiguration, ODGP has presented in this paper.

Keywords: Distributed generation, Optimal DG placement, Optimization techniques, Artificial intelligence computational techniques, Renewable energy sources.

Abbreviations: ANM, Active Network Management; ABC, Artificial Bee Colony; BA, Bat Algorithm; BFA, Brute Force Algorithm; BFOA, Bacterial Foraging Optimization Algorithm; BSOA, Backtracking Search Optimization Algorithm; CS, Cuckoo Search; DG, Distributed Generation; DS, Distribution System; DGA, Distributed Generation Allocation; DGP, Distributed Generation Planning; DSDR, Distribution System Dynamic Reconfiguration; DP, Dynamic Programming; DA, Dragonfly Algorithm; EA, Evolutionary Algorithm; FFM, Firefly Method; GA, Genetic Algorithm; HS, Harmony Search; ICA, Imperialist Competitive Algorithm; IWO, Invasive Weed Optimization Algorithm; LP, Linear Programming; MINLP, Mixed Integer Nonlinear Programming; NLP. Nonlinear Programming; NSGA, Non-dominated Sorting Genetic Algorithm; ODGP, Optimal Distributed Generation Placement; OO, Ordinal Optimization; OPF, Optimal Power Flow; PSO, Particle Swarm Optimization; PGSA, Plant Growth Simulation Algorithm, SQP, Sequential Quadratic Programming; SA, Simulated Annealing; TS, Tabu Search.

I. INTRODUCTION

Recent advances in utilization of non-conventional/renewable energy sources, its approaches towards various applications in connection with the methodologies and modifications have created an interest in the usage of the renewable sources for generating electrical power. In recent days all over the world, assets related to the renewable energy sources has effectively placed in electrical power systems with multiplying rate, in which DGs are the one that has abundantly introduced in the specific distribution system (DS). The electric power system organizers and controllers gain advantages by integrating DG units in the distribution systems, which depends on the attributes of DG units and the loads. Further, it again be contingent on the nearby assets of renewable energy sources and the circuit setup. The system is improved if all the DGs assets are optimally sized and located in required location. Though the integration of renewable energy sources with the distribution system has gained some benefits. Due to the uncertainty and fluctuations, DGs are meeting a few challenges in the DS. In the process of effective integration of DGs with DS, the power quality improvement and the stability of the system are considered to be the most significant issue.

In general, the distributed generation (DG) is defined as a small amount of electricity is generated by utilizing the non-conventional energy resources at distribution voltage levels and distributed to the customers [1]. In an DS, power loss is in the form of heat, due to the flow of current is very high in large distribution system. Specified power losses in transmission and sub-transmission lines depend upon 29% of the total power losses, while in DS accounts for 71% of total losses in the power system [2]. A few issues related to DG incorporating in distributed systems are a power loss, variations in voltage profile, service reliability, restoration and system stability have been overviewed in [3-6]. DG installation in the distribution system affects the practical features of the entire network and create a problem towards the electricity market worldwide [7].

Power losses can be reduced in the system through the network reconfiguration strategies or techniques. Mainly, the distribution feeder reconfiguration technique can be conveniently utilized for system planning and real-time controlling and operation. Network reconfiguration in an electrical distribution system incorporates design and maintenance, which is required to identify the suitable structure, by changing switch positions inside the network [8]. Interconnection to neighborhood plants is considered to be another strategy to reduce the total power loss for instance (mini-hydropower generating plants, wind turbine power plants, solar power plants and biomass energy plants) [9].

The literature on the various research work shows that the use of renewable energy sources can minimize carbon contamination or pollution by 61% rather than from traditional electrical power generation plants by 2040 [10]. Installing DGs in distribution system leads to improved load balance, improves voltage profile, energy efficiency and reliability when it is appropriately sized and placed optimally. Optimal distributed generation placement is defined as the most appropriate place for the installation of DG. Unacceptable DG size results in an increased total power loss. Therefore, optimal sizing and location of the DGs reduce the power loss by keeping the system stable [11].

The Distributed Generation Planning (DGP) is also known as Distributed Generation Allocation (DGA). The optimization techniques used for optimal DGP are Analytical techniques, numerical methods, society inspired algorithms, nature-inspired techniques etc. In past research works published, authors have taken a single objective function, to find the optimal DG allocation problem in such way to minimize system power losses [12-14], voltage profile enhancement [15-16], reduction of reactive power [17], DG size enlargement [18-19] and economy-oriented objectives [20-21].

In connection with this, a few review papers have published which are considering the network reconfiguration, ODGP, the optimal location of switching devices to solve service restoration problems in [22-24]. In continuation, the voltage sensitivity technique has implemented to maximize the accommodation capacity of the photovoltaic system provided for low voltage grids in [22]. Another method has been proposed in [23] based on the active power flow management, that leads to help for DG incorporation improvement. Another method knows as the Active Network Management (ANM), which comprises of multiple system-level strategies for better placement of DGs have presented [25-27].

Recent meta-heuristic algorithms have been implemented for solving DG placement problems such as Bacterial Foraging Optimization Algorithm (BFOA), Stud Krill herd Algorithm, Harmony Search Algorithm (HSA) [28-30], Grey wolf optimizer [29, 30]. Another concept knows as Greedy algorithm has implemented for solving a weighted set cover issue, in which the nearby available minimum number of critical switches have recognized for enhancing the restoration capability of a distribution system considering DG placement [33]. In the distribution system dynamic reconfiguration (DSDR) critical switches are involved dynamically to reduce the power loss considering DG location and size [34]. Mixed-integer linear programming problem based on branch and the bound algorithm has implemented to identify a set of critical switches used to operate based on intraday hours for its continuous operation [35].

A complete review based on the recent works published in the network reconfiguration, ODGP and optimal location of switching devices to solve service restoration problems has presented in this paper.

II. DG DEFINITION

Distributed Generation is a mini power generating a system to provide a small amount of energy to the customer loads through a utility electrical distribution system, defined in [36]. Some of the standard definitions of DG defined by the international organization has described [37-39].

Benefits of DG. As the rate of electricity consumption by consumers is becoming increasing rapidly, due to this integration of DGs in the radial distribution system is expanding. New technological improvement in DGs design has contributed to the generation of energy at low cost, emission and high efficiency. In [40], the application of DGs in a modern electrical power system has been introduced to fulfil the requirements of customer load demand continuously by checking the reliability and quality of the supply. The development in design and manufacturing of DG units apparatuses, continuous variations in load pattern and uncertainty of available fuels have created opportunities for the utilizing renewable/ non-conventional energy resources to generate power as per consumers load demand balance. Some of the advantages of DG installation are described in Table 1 [41-42] below.

Table 1: Distributed generation (DG) advantages [41-42].

Parameters	Advantages
Economic benefits	– Less maintenance and operation cost. – Cost of fuel consumption is less with renewable DG. – Purchase of right of way cost is less. – Equipment cost of purchasing is less.
Environmental benefits	– Environmentally friendly. – Reduce the maximum amount of greenhouse gas pollutant. – Less land requires to install renewable DG unit.
Technical benefits	– Improve the reliability of the electrical power system. – Reduction of Peak load demands. – Voltage profile and quality can be improved. – Better voltage regulation and fewer voltage flickers. – Reactive power can be control quickly, and losses in line are less. – Improve the overall efficiency of the system. – Reserve capacity power can be reduced. – Enhance the security of power utilities and critical loads.

Types and Methodologies of Distributed Generation: Generally, DG methodologies have classified into two types, namely renewable energy and non-renewable energy resources. The below Table 2 shows the types of DG methodologies and the DG methodologies with their characteristics [43-46].

Table 2: DG Technologies/Methodologies [43-46].

Different DG Technologies/Methodologies					
Renewable DG Technologies				Non-Renewable DG Technologies	
Contents	**Wind energy**	**Photovoltaic**	**Fuel cell**	**Gas turbine**	**Reciprocating Engines**
% efficiency	35-45	10-36	35-55	20-45	Diesel :35-45
Fuel used	Wind	Sun radiation	Methanol & Hydrogen	Natural gas & kerosene	Diesel, Bio-Diesel, Bío-gas.
Capacity range	0.2 MW- 4 MW	1kW-10kW	10kW-1MW	2MW-20MW	Diesel:15kW-10MW
CO_2 Emission(g/Kwh)	No emission	No emission	400-500	500-650	Diesel:600-650
Applications	Industrial and commercial application, Domestic Applications	Household, Industrial, Transportation, Communication and power generation.	Domestic & army applications, Transportation sector.	Reserve power generation, Transportation sector and commercial sector.	Standby and combined heat generation.
Advantages	No emission, Low Operation & Maintenance costs, low environmental impact.	No emission, Low Operation & Maintenance costs, less impact on environmental.	Compact, Low Operation & Maintenance costs, more efficiency, reliability and low emissions	Low Operation & Maintenance costs, low emission, high operating speed.	Capital Cost is low, high efficiency and reliability.
Disadvantages	Noise pollution and Telephone interference	Electromagnetic Field-effect, loss of natural environment and biodiversity loss.	High Installation Cost.	Low Efficiency & High Capital Cost.	More noise, High maintenance cost.

III. DISTRIBUTED GENERATION

DG is termed as a mini generating unit from kW to MW and also an energy storage device which is located/placed near to customer loads, distribution substations and transmission substations in terms of distributed energy resources.

Significance of ODGP. To construct a reliable electrical distribution network, DG plays a vital role in the future upcoming grids. To minimize the impact of power stations on economic and environmental conditions, DG such as renewable energy sources, diesel generator and energy storage devices is a better choice. DGs placement can minimize transmission, the distribution cost of generation and provide a way to consume energy under the peak load conditions and increase the reliability of the system. To achieve maximum benefit from DGs, the optimum sizing and location should be planned carefully, considering different criteria like climatic conditions and availability of resources [47]. DGs integration has an impact on the operating condition and reliability of the distribution system. If the DG is placed inappropriate, cause an increase in power loss and instability of the system. Therefore, the appropriate placement of DGs enhance the system power quality, improves system voltage profile, minimize harmonics and system losses.

DG scheduling and planning is a significant issue for distributing real & reactive power to the electrical distribution system. Some DG planning methods are (a) size only (b) location (c) size and location (d) size, location and numbers and (e) size, location, number and type. The main advantages of ODGP are:

– Minimize active and reactive power loss
– Reduces power system fluctuations
– Enhance available electrical power transfer capacity
– Improves power system reliability and security
– Maximize power system load ability.

– Enhance the stability of system, voltage, frequency and stability of rotor angle
– Minimize conjunction of the line power and
– Increase the range of operation of the system.

Effects of DG. The impacts of DG have classified as follow: Environmental, Economic and Technical impacts. Due depletion of fossil fuels, an increase in pollution and changes in climate condition has origin the power generation through renewable sources. According to the literature published by many researchers, academic persons, 75% of the pollution in the environment around the world has generated due to fuel-burning [48-50]. By implementing recent DG technologies like renewable energy sources to generate power can reduce the emission of carbon content particle releasing into the atmosphere. The large thermal power generating station release a large portion of greenhouse gases into the atmosphere, which are primary contributors to global warming [51].

Some of DG technologies which do not consume fossil fuels such as wind energy, solar photovoltaic system and hydropower plant can reduce the greenhouse gases to the maximum. The economic benefits which the utilities obtain by shifting to DG integration are reduced in fuel cost, reservation of power storage, upgradation of the generation, maximization of the protection for critical loads, minimization of operating cost during peak hours and minimization of the maintenances and operation cost [52]. The technical problems which occur in the distribution system, when DG is placed in an inappropriate location are real and reactive power losses, excess energy, voltage variation and unstable reliability in system operation [53-55].

Selected Objectives for ODGP. Generally, the main goal concerning ODGP is to minimize total power losses in the power system. Other objectives like voltage profile improvement, current reduction in delicate lines, the reactive power loss minimization and network MVA capacity increment have been considered as fitness functions for optimization. The primary optimization objectives for ODGP are shown in Fig. 1.

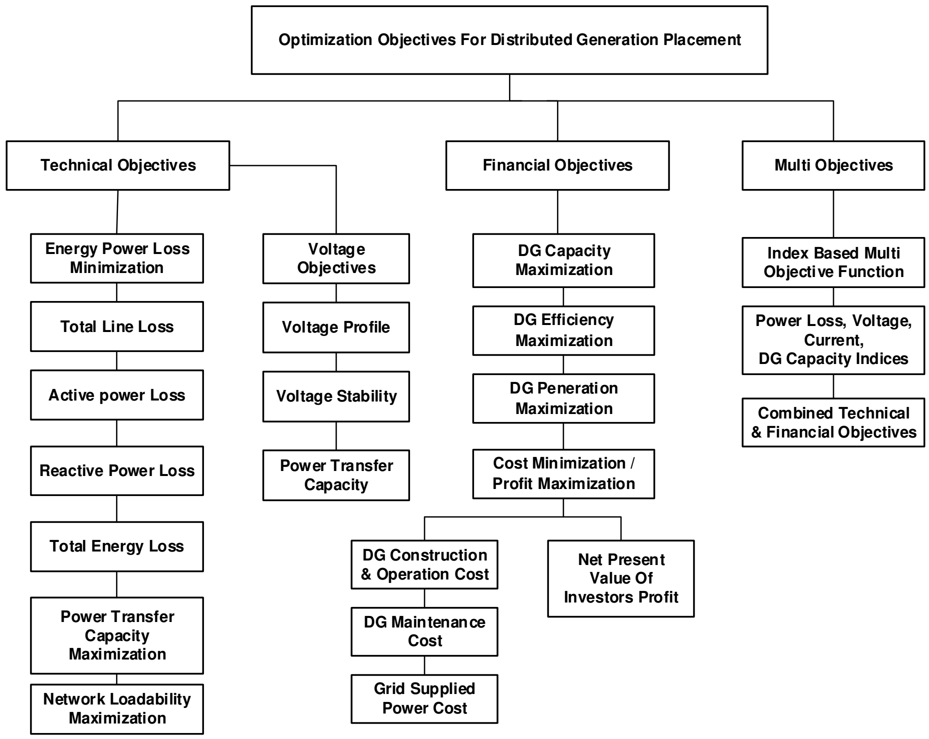

Fig. 1. Objectives in distributed generation placement/allocation.

Number of DGs. Dependent on DGs connected to the distribution system, the ODGP problem is classified as:
– Single DG and
– Multiple DGs installation.

Load Variable Levels. The different types of load/stack variable levels modelled in DG location are as follows: single stack, multi-stack and time-dependent stacks, etc., distributed along buses/lines.

Constraints. The majority constraints considered in the design of ODGP are as follows:
– Bus voltage, voltage drop limits,
– Line, transformer overloading, capacity limit,
– Total harmonic voltage distortion limit,
– Short-circuit level limit,
– Reliability constraints, e.g., SAIDI, SAIFI.
– Power generation limits,
– Budget limit, Power flow equality constraints and
– DG penetration limit. he variables

Comprehensive Algorithm for ODGP. The Comprehensive algorithm for ODGP in the distribution system is explained as [56]:
Step 1: Initialize the system data.
Step 2: Execute the power flow analysis.
Step 3: Estimate bus voltage, system losses and short-circuit current at the bus.
Step 4: Check if constraints satisfy or not.

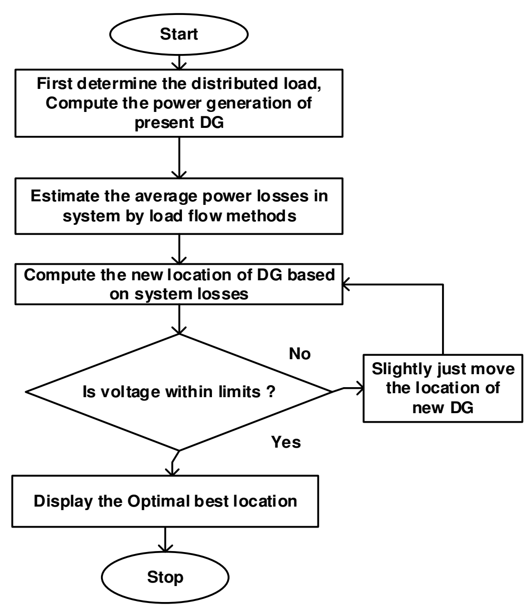

Fig. 2. ODGP in radial distribution system.

Step 5: If satisfies initialize weight factor, and evaluate the objective function.

Step 6: Incorporate required optimization method to optimize the objective function.
Step 7: Else estimate the new position and sizing and go to step 2.
Step 8: Check if the solution is the best fit for objective function or not?
Step 9: Yes, means calculate indices values or not means go to step 7.
Step 10: Analysis of the weight factor and print the best-fit position and size for DG placement, otherwise go to step7.
The flowchart used for determining ODGP in a radial distribution system is depicted in Fig. 2.

IV. OPTIMIZATION METHODS AND ALGORITHMS

Several methods have been implemented for ODGP in the electrical distribution system areas [57, 58]:
1. Analytical Optimization Methods.
2. Numerical Methods.
3. Modern Higher-Level Algorithms.
4. Nature Inspired Techniques
5. Other Technique for Future use.

The most commonly used optimization methods and algorithms for ODGP are summarized in Fig. 3.

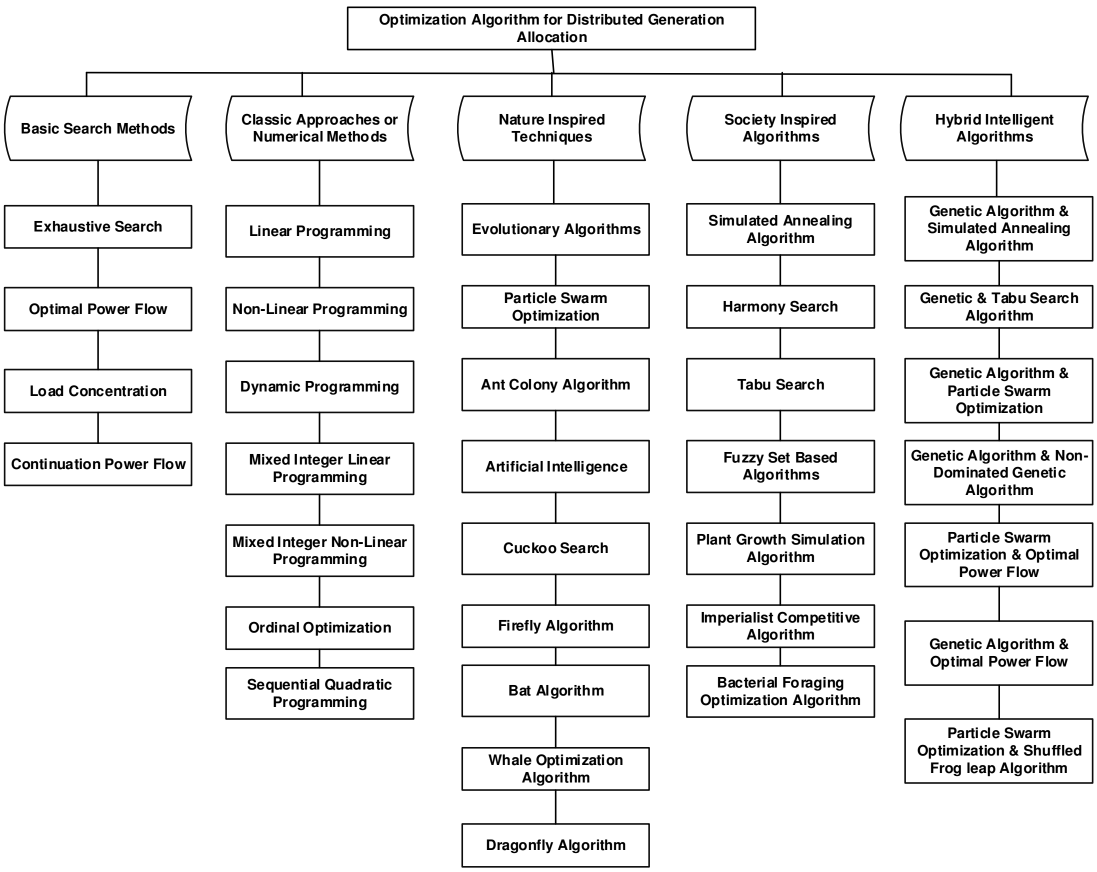

Fig. 3. Different optimization algorithms for optimal distributed generation placement.

Analytical Optimization Methods. Analytical optimization methods have implemented based on the 2/3 rule concept. In this concept a 2/3 size of DG, which is having a received generation at 2/3 span of the line connected to a network. This rule is applicable mostly for loads having a uniform distribution. Two analytical methods have proposed by C. Wang and Nehrir for optimum location of DG in the system considering fixed size [59]: The primary method is valid to radial and the other to a meshed electrical distribution system. Another analytical method has been proposed for ODGP based on "exact loss formula" by Acharya [60].
Gözel has introduced a technique for ODGP using loss sensitivity factor depending on the equivalent current injection process [61]. Another method has been suggested [62] for obtaining the optimal location/placement of multiple DGs, including "Kalman filter algorithm" to define their size. A set of regular expressions has developed for finding the optimum size, including different types of DGs power factor to reduce the system power losses [63, 64].
(a) *Eigen Value-Based Technique:* To analysis, the stability condition of the electrical power system Eigen value-based technique is utilized. Stability places a vital role in the effective operation of the electrical system under loaded condition [65].
(b) *Sensitivity Based Method:* This method has implemented based on the variation of one variable value, which in turn affects the desired value of a variable. As per the literature review, the authors have

proposed the sensitivity-based method considering loss minimization for ODGP in the electrical distribution system [66-68].

(c) *Index Method:* This method has implemented depending on the theory of variation of constraint value from an actual value. This method is mainly used for reliability determination, as proposed [69].

Numerical Methods. Some of the underlying numerical methods used for ODGP are:

(a) *Gradient Search Method:* This method has proposed by authors for the ODGP in meshed networks, including constraints related to fault outages/levels in the system [70, 71].

(b) *Sequential Quadratic Programming (SQP):* SQP is proposed for resolving ODGP models considering different constraints involving fault level scenarios [72].

(c) *Linear Programming (LP):* Linear programming method is mainly utilized for constructing ODGP models, aiming to attain maximum distributed generation penetration in distribution system [73].

(d) *Nonlinear Programming (NLP):* This method have been used for placement of minimum number DG in both distribution system, i.e. radial system and meshed system, with an objective improving voltage stability of system [74]. NLP methods are also used to construct and solve deterministic models, which are used for the ODGP formulation considering AC optimal power flow [75]. MINLP is also a method used for ODGP to reduce system power loss and to enhance voltage stability limits [76].

(e) *Dynamic Programming (DP):* This method has been implemented to resolve an ODGP design with an objective function to maximize the distribution network operator profit by considering different load conditions [77].

(f) *Ordinal Optimization (OO):* An Ordinal Optimization technique is employed for obtaining the ODGP by considering the trade-off among loss minimization and for capacity maximization of DG [78].

(g) *Exhaustive Search:* Exhaustive Search technique has been used for analyzing the behavior of load demand concerning time-dependent and generation in the system; once a DG is placed in a large distribution system. This search method is used for ODGP with an objective function to maximize the reliability of a system for a particular DG size [79].

(h) *Optimal Power Flow (OPF):* A constraint nonlinear optimization method have been used mostly to solve many problems raised in power system related to reliability of supply, DG placement, voltage profile improvement and minimization of power losses. These OPF methods are basic search methods utilized by researchers for ODGP in distribution system [80, 81].

(i) *Mixed Integer Non-Linear Programming (MINLP):* This technique is formed on a combination of linear and nonlinear programming, mixed-integer linear and nonlinear programming methods, depending on the required problem defined for ODGP. MINLP can be applicable for different functions like discrete, continuous variables and non-linear. The technique provides an accurate, reliable solution for multi-objective problems [82, 83].

(j) *Continuous Power Flow Method:* This technique have been well known for solving the non-linear equation of the system. By using this technique, voltage collapse in the system can be computed by using the system load flow equation. If the matrix has value as zero, then it is represented as a voltage collapse condition. A method has proposed in [84] to identify a sensitive bus to place a DG in the system.

Modern Higher-Level Algorithms. Due to stochastic nature in power generation by renewable energy sources, the proper placement, sizing & location of DGs in the distribution system play a pivotal role. Many socially inspired algorithms have been integrated with different heuristic solvers for solving DG placement in the system. For solve the ODGP optimization problem, many conventional optimization methods, advanced hybrid algorithm combine with fuzzy algorithms have been implemented by researchers in the literature survey.

(a) *Simulated Annealing (SA):* This algorithm have been implemented by Kirkpatrick, Gelatt and Vecchi in the year 1983, based on a random search method, to evaluate huge combinatorial optimization issues. Limitation of this algorithm possibilities of getting entrapped in the local minima when tolerating and rejecting new results. This algorithm have an initial random solution for the defined problem, later updating one component of the solution iteratively towards the goal, to obtain the best solution for the considered optimization problem. This technique is formulated for ODGP depending on objective function to minimize power loss and improvement of voltage profile [85].

(b) *Harmony Search (HS):* Zong Woo Geem have introduced the algorithm in the year 2001 [86]. The harmony search algorithm is a metaheuristic algorithm formed based on music and inspired by music harmony combining different sounds from a visual point of view. This technique has formulated for ODGP depending on the objective function to minimize the power loss [87]. The flowchart for the harmony search algorithm is depicted in below Fig. 4.

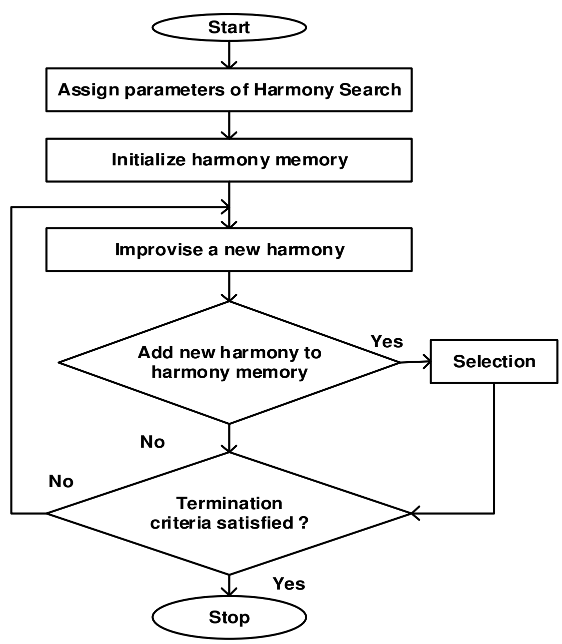

Fig. 4. Harmony search algorithm flowchart.

(c) *Tabu Search:* This algorithm have been first introduced by Glover and McMillan in the year 1986, for computing optimization problem based on the performance of the human memory. To obtain a better solution within a smaller number of iterations for combinatorial problems, the tabu search algorithm is preferred more. This technique provides an accurate, reliable solution in less time for multi-objective problems considering both ODGP and location of reactive power sources [88]. The flowchart for the algorithm is shown in below Fig. 5.

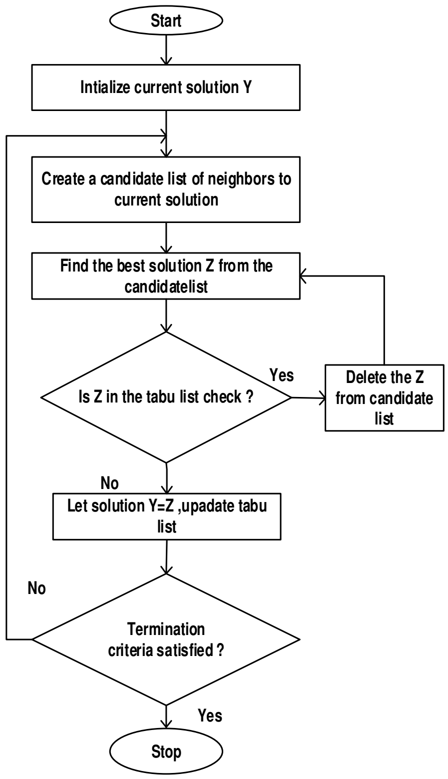

Fig. 5. Tabu search algorithm flowchart.

(d) *Fuzzy Based Algorithms:* Fuzzy based algorithms are powerful tools used for evaluating the stochastic nature of systems, modelling and planning [90]. A two-stage approach has implemented for ODGP, in which Fuzzy is utilized to determine the ODGP. In the next stage, the ABC algorithm has used for obtaining the size of the DGs, considering the minimization of losses [91].

(e) *Plant growth Simulation Algorithm (PGSA):* This algorithm is a quick method which doesn't need parameters to be tuned more, when finding an optimal value. This method is used for ODGP and also for placement of capacitor in radial distribution system [92, 93].

(f) *Imperialist Competitive Algorithm (ICA):* It is one of the evolutionary algorithms that begins with primary population and separated into various colonies as imperialists along with kings. This technique is more suitable, efficient and accurate than other methods for stage-based computation ODGP [94].

(g) *Bat Algorithm (BA):* This algorithm have been proposed by Yangin in the year 2010, based on reverberation area properties of bats with fluctuating loudness and vibrations rates of release. In [95], ODGP in radial distribution system has proposed by using Bat algorithm. The flowchart for the Bat algorithm is shown in Fig. 6.

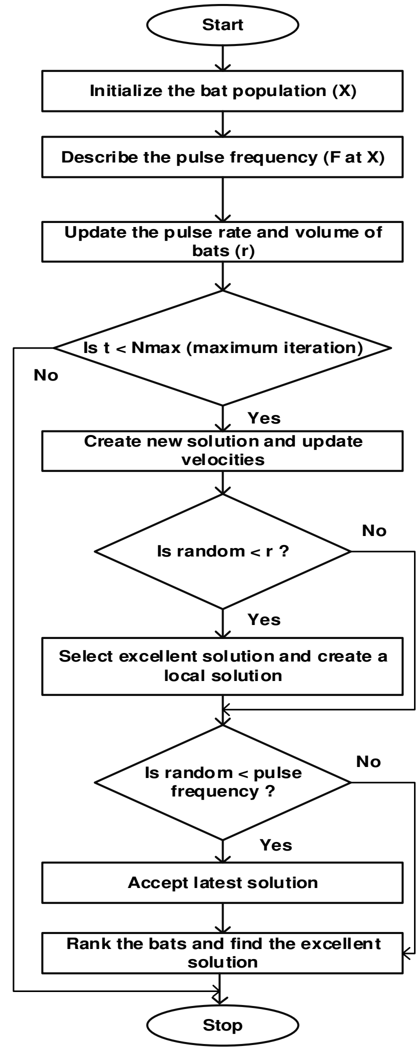

Fig. 6. Bat algorithm flowchart.

(h) *Brute Force Algorithm (BFA):* BFA is a secure problem-solving algorithm. This method comprises of calculating solution for all candidates in orderly and explores whether the candidate satisfies the problem statement or not. It will assist for evaluating the execution of the other algorithm by seeing the amount they diverge from actual result computed using BFA which is proposed by Mena and García (2015) [96].

(i) *Bacterial Foraging Optimization Algorithm (BFOA):* BFOA comes under the field of Bacteria, swarm optimization and computational intelligence, and metaheuristics. This algorithm is inspired by chemotaxis behavior of bacteria, which will observe chemical gradients in the environment and move towards precise signals. The information processing strategy of the algorithm is to aloe cells for stochastically and collectively swarm toward optima [97]. BFOA have been proposed for ODGP in the radial distribution system, with an objective function to minimize the line losses considering various constraints [98].

(j) *Invasive Weed Optimization Algorithm (IWO):* Mehrabian, Caro Lucas in the year 2006 have introduced an IWO algorithm, based on the stochastic optimization algorithm, which is inspired on the behaviour of weeds. This algorithm has utilized for finding the optimum size and location of DG with an objective function power loss reduction combining loss sensitivity factor technique. A multi-objective method for ODGP in the distribution network with different load models has proposed [99].

(k) *Backtracking Search Optimization Algorithm (BSOA):* BSOA is a newly proposed evolutionary algorithm used for obtaining the solution to the problem including nonlinear functions, non-differential functions, real-valued and complex numerical optimization functions. This algorithm is more comfortable, faster and efficiently applied for different statistical techniques [100-102].

Nature inspired Algorithms. Several natural inspired techniques implemented by researchers are as follows: Evolutionary Algorithm, Genetic Algorithm, Particle Swarm Optimization, Dragonfly Algorithm, Bee Colony Optimization Algorithm Whale Optimization Algorithm, Ant-Colony Algorithm, Cuckoo Search Optimization Algorithm and Firefly Optimization.

(a) *Evolutionary Algorithm*: An Evolutionary Algorithm is a generic population-based meta-heuristic algorithm used for creating the solutions to the problem, based on the natural-based selections (recombination, mutation, selection and reproduction, etc.). This algorithm have been developed based on the basis of a natural phenomenon for obtaining the optimal solution to a problem defined. In general, the necessary steps involved in the algorithm namely, the first step is generating the initial population of individuals randomly (first generation). The second step is identifying the possible solutions and update them as per the approach to improve these solutions. The third step is finding for the optimum solution to the defined problem considered by repeating the second step until the convergence criteria have satisfied. This algorithm has been proposed for optimization of position and size of the DGs with an objective to minimize power loss and maximize the system voltage profile [103].

(b) *Genetic Algorithm:* Genetic Algorithm (GA) have been mostly used optimization algorithm that replicates the evolution and transformation process in nature. Generally, GA is applied for large optimization problems to obtain a globally optimal solution. GA have been using in the optimization of DGs placement and location, business purpose, and for advanced machine learning concepts because it is easy to model and understand. GA is implemented for finding out the ODGP with the help of the multi-objective cost function in consideration with the parameters like cost of DGs, active power loss and reliability indexes like SAIDI and SAIFI [104].

Another improved version of GA known as Non-dominated Sorting Genetic Algorithm-II (NSGA-II) have been used in distribution systems for dynamic reconfiguration [105], considering a multi-objective function minimizing the cost of operating system and maximizing system reliability. An improved NSGA have proposed for ODGP in the radial distribution system by involving time sequence characteristics of the load and distributed generator output [106]. The flowchart for the Genetic algorithm is shown in below Fig. 7.

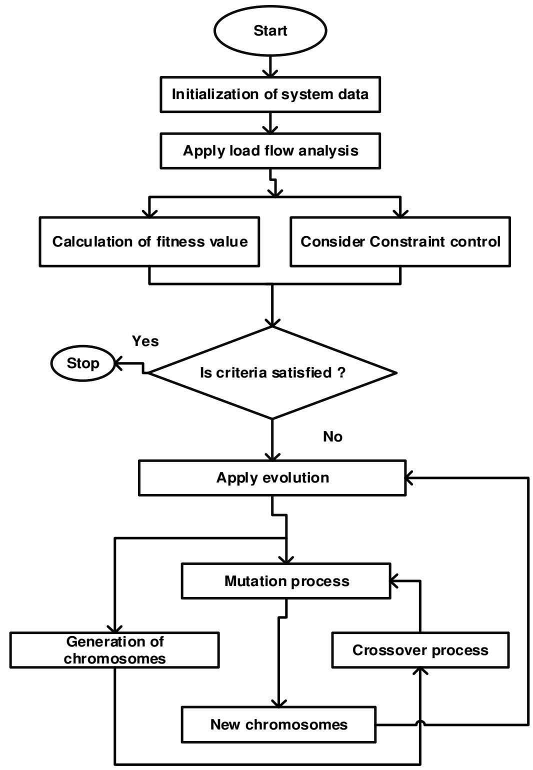

Fig. 7. Genetic algorithm flowchart.

(c) *Particle Swarm Optimization (PSO):* James Kennedy and Russell Eberhart have introduced the PSO algorithm in the year 1995, it is considered as the vigorous, stochastic optimization procedure based on the manoeuvre and the intelligence accomplished with the swarms. PSO algorithm is mainly related to the population and pretends the social behavior of the fish schools or bird flock. In this connection, it is considered that every individual available in the total population are designate as particles. Further considered to be moving in the multi-dimensional search space in steps of the time domain [107]. In the process of search in the time domain, the new location of the particle have identified with respect to the current location of the particle, best-experienced state by the particle itself (Individual Best) and the best experienced by surrounding neighbors to the particle (Global Best) [108].

PSO algorithm have implemented for finding the Pbest value and Gbest value mostly for optimization problem which are operating under different load conditions [109]. For integrating the renewable energy sources in radial and Multi-phased DS under unbalanced condition, the concept of PSO is applied for evaluating the optimal location and sizing of DG is mostly used [110]. The researchers have used the PSO algorithm to identify the ODGP & sizing of multiple DGs in DS to minimize the losses. The hybrid PSO and HBMO algorithms have used for voltage profile improvement in DS [111,112]. The flowchart for the PSO algorithm is shown in below Fig. 8.

(d) *Dragonfly Algorithm (DA):* Mirjalili have first introduced the dragonfly Algorithm in the year of 2015, based on the static and intellectual behavior of the dragonflies and the swarm intelligence of them, which is narrated by nature.

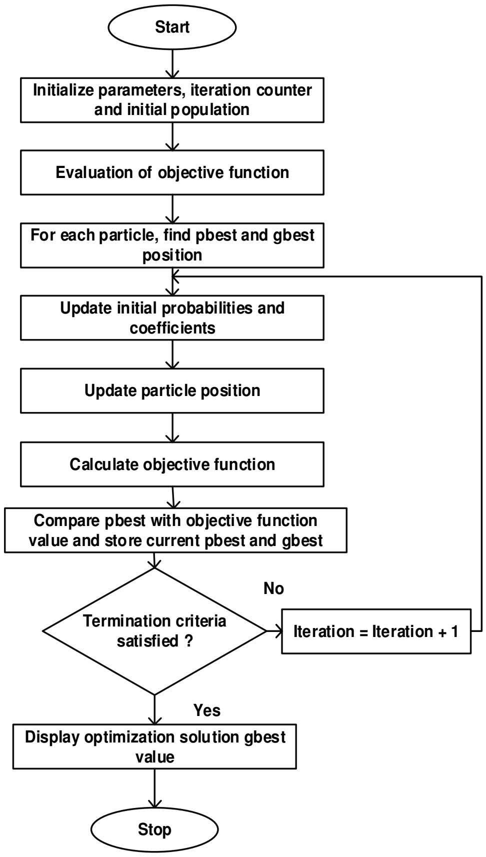

Fig. 8. PSO Algorithm flowchart.

DA have applied to find an optimal unit size of DGs generation to improve voltage regulation, profile, stability and power loss reduction as well as for the economic benefits [113]. The flowchart for the Dragonfly algorithm is shown in Fig. 9.

(e) *Whale Optimization Algorithm:* Whale Optimization Algorithm have been implemented to find the optimal size & location of DGs, to evaluate multi objective functions based on the system total power loss minimization, improvement in voltage profile and the reduction in operating cost in consideration with equality and inequality constraints [114].

(f) *Ant Colony Optimization Algorithm (ACO):* ACO algorithm have been implemented based on the behavior of the social insect (ant) for finding the shortest route for their food needs [115]. These inturn help to find out the possibility of solving optimization problems merely by using the simulation tools [116]. The Ant colony system is an improved version of ACO, which further provides better simulation results in various engineering problems [117].

Hence, ACS have been applied for identifying the optimal location of the fixed recloser switch and the position of ODGP, to enhance the reliability of the DS. The flowchart for the Ant colony optimization algorithm is depicted in Fig. 10.

(g) *Artificial Bee Colony (ABC):* Karaboga (2005) [118] have used ABC algorithm based on the intelligent behavior of the honey bee insects/swarm for finding optimal value.

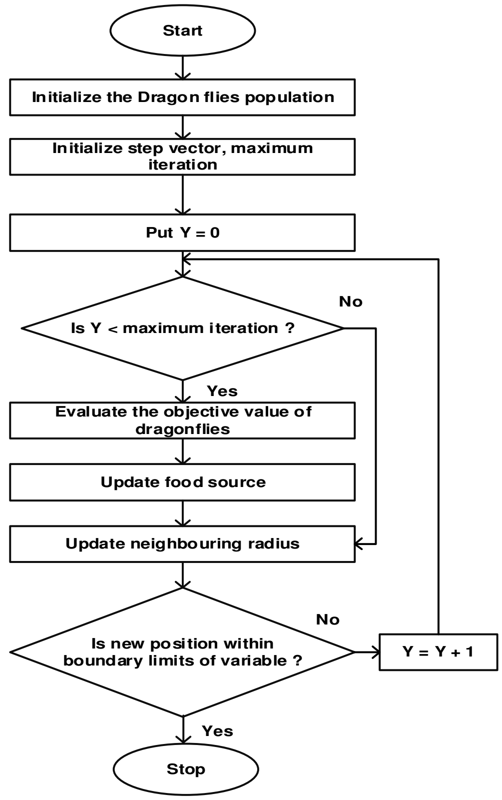

Fig. 9. Dragonfly Algorithm flowchart.

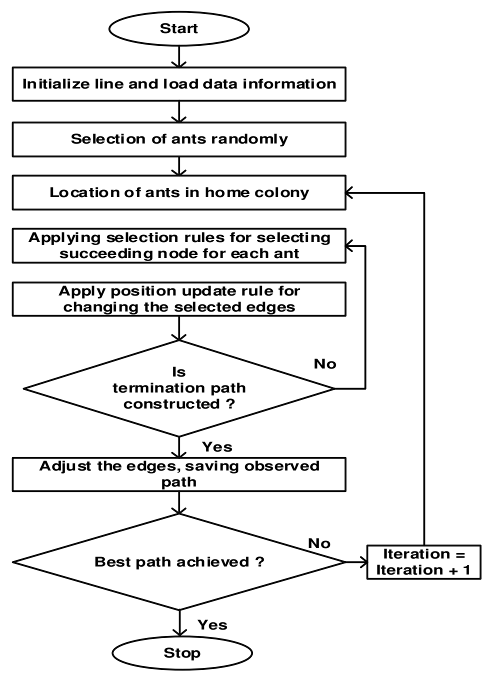

Fig. 10. Ant colony optimization Algorithm flowchart.

The sufficient colony size, number of iterations and the variable limitations has considered to be the critical control parameters in ABC. These parameters have to defined initially by the concerned user of the algorithm. At the beginning stages ABC algorithm have effectively utilized for solving the numerical based optimization problems [118]. Later the usage of algorithm has prolonged to other applications such as the problems related to constrained, unconstrained and even some combinatorial issues [119–120]. Since, the algorithm has specific advantages like robustness, simple and flexible in solving problems has made to use this algorithm more for solving the optimization problems. ABC is mainly dealing with the position adjustments made by the bees in the nest for the choice of food sources, concerning their own as well as their nestmates involvement. Accordingly, in a given multidimensional search domain, the artificial bee can move together with other existing bees in the nest. Hence, the significant criteria considered in ABC concentrate only with two control parameters which can be appropriately tuned as related with the GA and PSO algorithms. In general, the ABC optimization algorithm is effectively utilized for analyzing the transient behavior of the grid interconnected DGs [121]. The flowchart for the Artificial Bee Colony algorithm is shown in below Fig. 11.

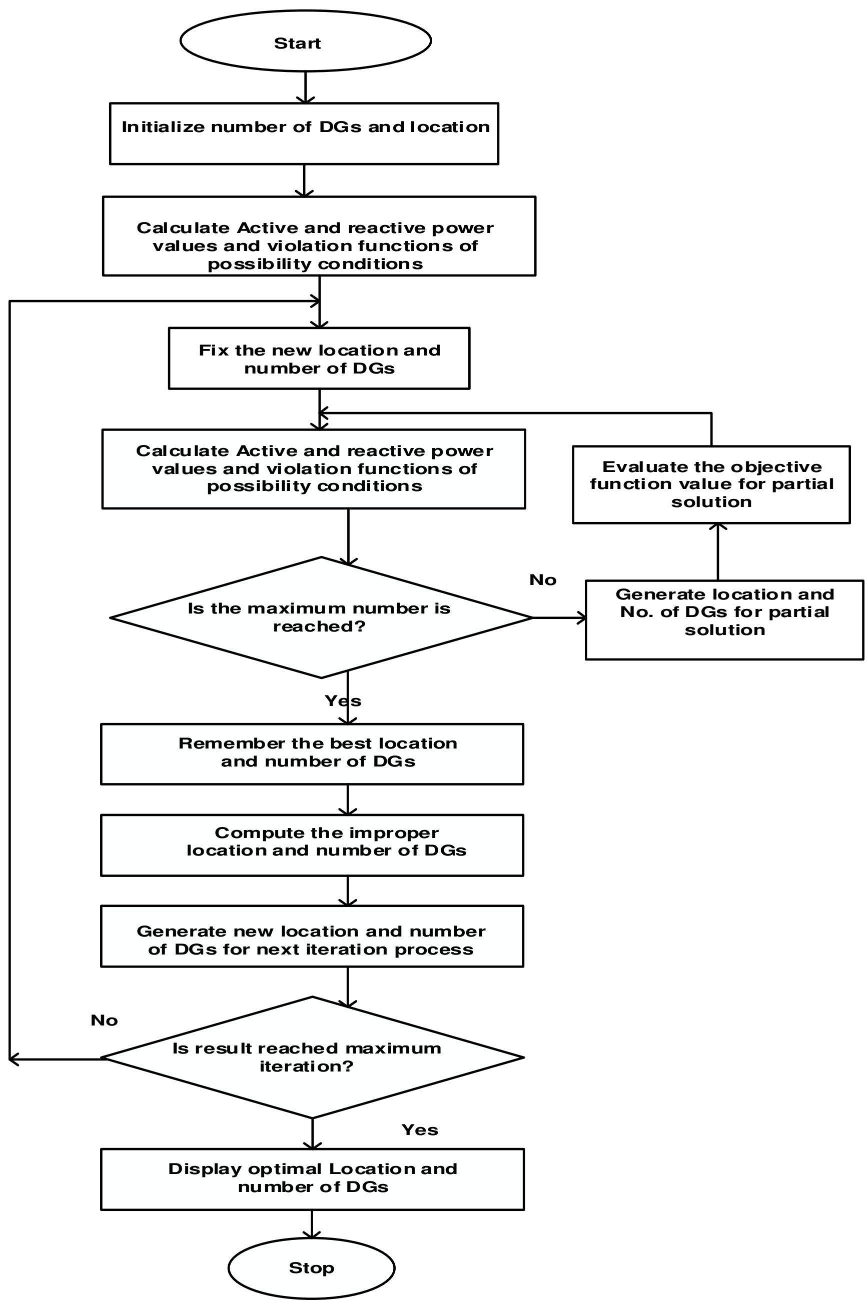

Fig. 11. Artificial Bee Colony Algorithm flowchart.

(h) *Cuckoo Search (CS):* The Cuckoo Search Optimization (CSO) have been implemented in 2009 based on inspired by the parasitic egg-laying of the cuckoo species in the other host bird's nest [122,123]. For better performance and avoiding trapped in local extremums, a portion of the new generation should be generated randomly and far enough from the latest best solution. The CSO have implemented for the integration of biomass and solar-thermal DGA, considering loss minimization and voltage profile improvement [124]. Moravej & Akhlaghi used CSO for voltage profile improvement, which is done by using two regulation and variation indexes, and power loss reduction for ODGP [125].

(i) *Firefly Method (FFM):* The Firefly Algorithm is a swarm knowledge based on the stochastic search method. FFM can be utilized for optimization and to pursue promising areas called a solution space. The algorithm is stimulated by the phenomenon of explosion fireworks and sparks created inside a space around the fireworks in the sky.

The algorithm manages to allocate properties between firework swarms when penetrating for solutions consistently. The Firefly method is inspired by the ideal model of the fireflies flashing behaviour. Generally, the flashing is being done to attract other fireflies. This technique consists of three main rules, as follows [126], first fireflies in the population are of the same gender each of them can be attractive to others towards it. Next, the brightness and consequently, the attractiveness decrease with distance increase. Finally, the fireflies brightness have derived from the nature of the objective function search space. The brightness of a firefly dedicates its attractiveness, and the brighter one pulls the less bright one. The two major challenging issues in FFM are attractiveness and light intensity variation formulation. The FFM have been implemented for ODGP aiming to minimize the active and reactive power losses, voltage profile improvement for various models of loads, line current, level of a short circuit, and total absorbed apparent power of the network [127]. The flowchart for the firefly algorithm is shown in Fig. 12.

(j) *Hybrid Intelligent Algorithms:* Hybrid Intelligent Algorithms (HIAs) is known as a combination of different artificial intelligence methods working in parallel or cascaded mode to solve an optimization problem. Some of the different combination of existing meta-heuristic methods for ODGP, including Genetic-Tabu search (GATS) in [128], Genetic-Particle Swarm Optimization (GAPSO) in [129] the flowchart is depicted in Fig. 13, Genetic-Optimal Power Flow (GAOPF) in [130] and the Grasshopper Optimization Algorithm (GOA) and Cuckoo Search (CS) technique in Fig. 14. Merit-based comparison between different optimization techniques are discussed in Table 3 below, and Comparison of Analytical and Intelligent methods of sizing and location of DG in the distribution system are discussed in Table 4.

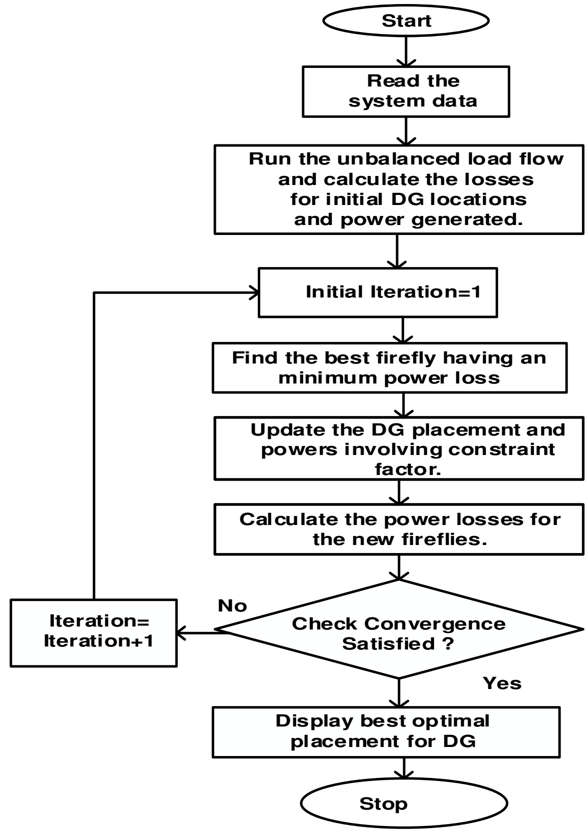

Fig. 12. Firefly Algorithm flowchart.

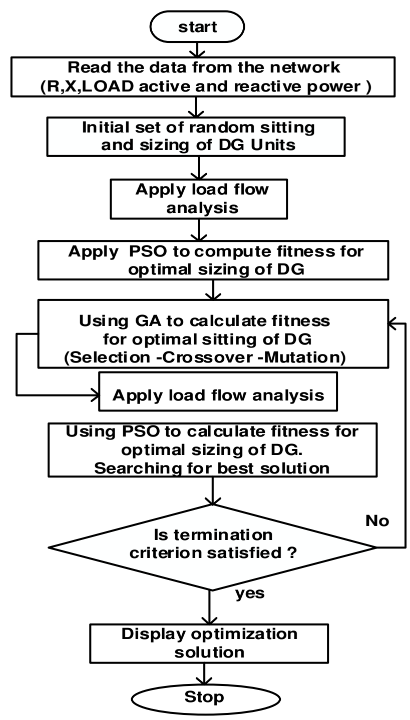

Fig. 13. Genetic-Particle Swarm Optimization (GAPSO).

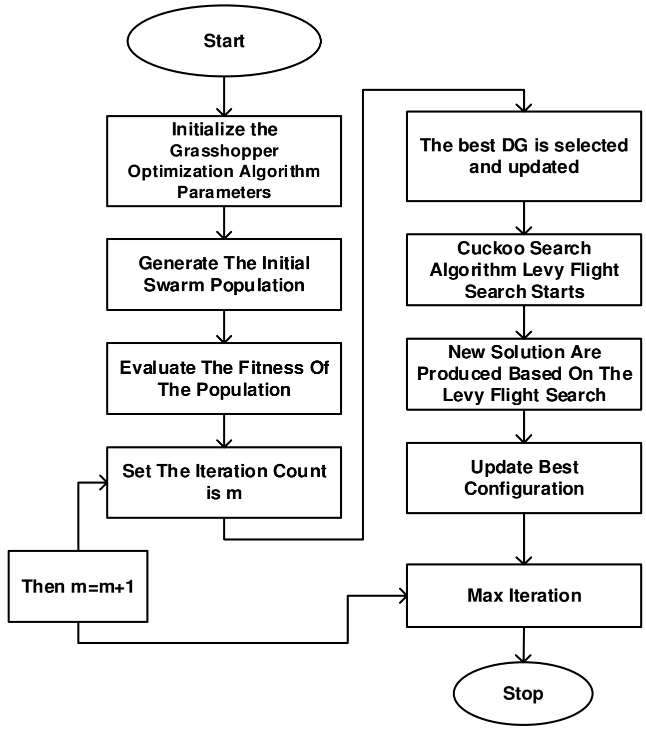

Fig. 14. Grasshopper Optimization Algorithm (GOA) and Cuckoo Search (CS) technique.

Table 3: Merit-based comparison between different optimization techniques.

S. No.	Goals	Methods	Advantages	Disadvantages	References
1.	Minimize total system power losses.	Analytical Based Methods	Accurate and efficient method.	More time is required for the complex system.	59,60, 61,63.
2.	Reduction of system losses as a single objective.	Kalman filter algorithm	Complexity is less	Results obtained are Inaccurate.	62
		Sensitivity Based method	Reduction in Search space and losses.	Probability distribution require more information.	67,68, 69
		Artificial Bee Colony Optimization	Results obtained for global optimization are excellent.	More dependent on control parameters linked to the algorithm, less efficiency.	118,119, 120,121
		Particle Swarm Optimization.	The optimal method to place DG in the distribution system.	For a large number of functions in the system, it provides an unfortunate result.	107,108, 109,110
3.	Losses minimization and voltage profile improvement.	Continuous Power Flow method	More efficient, effective, robust and capable to increase the penetration level of DG in the system.	To analysis the voltage stability of the system more information required.	84
		Plant growth Simulation Algorithm	No external crossover and mutation rate information is required.	The quality solution cannot be obtained.	92,93
		Particle Swarm Optimization.	The optimal method to place DG in distribution system easily, a high degree of accuracy.	For a large number of functions in the system, it provides an inefficient result.	111,112
		Backtracking Search Optimization Algorithm	Provide good result for global optimization.	Crossover strategy is non-uniformly followed; only one direction is allocated for each candidate based on random strategy.	100,101, 102
		Bat Algorithm	Efficiency, accuracy is more when compared to other algorithms.	By adjusting parameters values, the convergence rate is more affected.	95
		Bacterial Foraging Optimization Algorithm	More convergence, efficient and accurate than PSO, GA algorithms.	Problem arises in global optimization	97,98

		Genetic algorithm combined with optimal power flow and sensitivity analysis method.	Efficient and large for complex systems, required less computation time. Transmission losses are reduced more effectively.	Computation of mathematical formulae is more difficult, involved more parameters.	80,81,66, 67,69,105
4.	Improvement in voltage profile as one objective function.	Harmony Search (HS)	Have the capability to handle both continuous and discontinuous functions. Provide proper global search.	Local convergence speed is slow.	86,87
5.	Reduction of system losses and cost.	Brute Force Algorithm	Required less time to get an optimal solution and search space is also less.	Effectiveness suffered and not applied for optimization.	96
		Particle Swarm Optimization.	Most optimal method to place DG in distribution system easily, a high degree of accuracy.	For a large number of functions in the system, it provides an inefficient result.	112
6.	Reduction of system losses and cost, improvement of voltage profile and system load-ability.	Hybrid algorithms.	A high degree of accuracy, capable of handling all types of loads as DG penetration rate increases and provide accurate location and size of DGs.	Challenging arises in selecting the best solution for DG location. More time is required for computation.	128,129, 130.

Table 4: Comparison of Analytical and Intelligent techniques of sizing and location of DG in distribution system.

S. No.	Analytical technique	Nature Inspired Techniques
1.	An analytical method is well suited for finding out local maxima and minima value of both continuous and differentiable functions.	The intelligent optimization technique is suited for finding out local and global optimum solution for constrained, discontinuous and non-differential functions.
2.	These methods provide accurate optimum solution and time taken for computing is less, and it is not easy to implement.	These methods provide optimum near-optimum solution and time taken for simulation is more, and it is easy to implement.
3.	In this method, the optimization function have to be differentiable.	In this method, optimization function need not be differentiable.
4.	These methods are not suitable for large system and complex problems, and convergence problem does not exist in this method.	These methods are suitable for large system and complex problems, and premature convergence problem does exist in this method.
5.	These methods during modelling involve a set of nonlinear equations that might be difficult to compute.	These methods have no such types of difficulty faced during the modelling process.

V. CONCLUSION

This paper presents a complete description of the recent works published in DG placement and network reconfiguration considering DGs. Integrating DGs within the network improve the power system security, reliability, system power factor, system voltage profile, load-ability is an enhancement, improve stability of the system and also power transfer capacity of the system. The most frequently used technique for the solution of the ODGP problem is the genetic algorithm, harmony search algorithm, PSO, artificial bee colony, cuckoosearch, bat algorithm, tabu search, firefly algorithm, whale optimization algorithm, grey wolf optimizer,bacterial foraging optimization algorithm and hybridheuristics algorithm and artificial intelligence methods. Finally, it is concluded that the Artificial intelligence methods are more preferable to DG planning in DS. Hybrid optimization methods yield better results in DG planning for large scale power systems.

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