# Optimal Placement of Distributed Generation in Distribution Network: A Review on Hybrid Techniques

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***Abstract*— The integration of DG provides many benefits to the distribution system. To integrate DG, a proper location and size need to be taken into consideration. Poor planning of DG integration may lead to severe impact to the power system. Therefore, the proper technique is required to find the optimal location and size of DG to ensure the distribution system can deliver a reliable power supply to the consumers. Throughout the years, there have been a lot of techniques being proposed to optimally allocate DG into the distribution network considering various objectives. From conventional techniques to metaheuristic techniques and hybrid techniques, all of them can provide optimal location of DG to solve either single objective or multi-objective functions. However, hybrid techniques now have become more attractive to researchers as it gives better performance and can eliminate some of the drawbacks available in conventional and metaheuristic techniques when working individually. Thus, this paper presents a review on Hybrid Techniques for Optimal Placement of Distributed Generation in Distribution Network. In this paper some of the hybrid techniques available in the past and recent literature were reviewed by focusing on how the technique can provide optimal location and sizing of DG to solve various objective functions such as minimizing power losses, improving voltage stability and reliability in power system. A summary of hybrid techniques is also presented in this paper. The review shows that the hybrid techniques provide better performance compared to conventional techniques available in the literature.**

***Index Terms*— Distributed Generation, Distribution System, Optimal Placement, Hybrid Technique**

## I. INTRODUCTION

One of the main aspects in the development of efficient power systems is planning. The integration of distributed generation (DG) units into a distribution network is one of the methods. Traditionally, power being supplied to the consumers by a centralized power generation system which consists of a few large generation systems and complex electricity transmission network for final use. Up to hundreds of megawatts, this generation system often has a large capacity, and the power flow is unidirectional. The centralized power generation often implicates high cost, extreme transmission losses and sometimes not environmental friendly [1]. As a result, the integration of DG units has become one of the main interests in power system planning.

There are many definitions of distributed generation that can be found in literature in terms of location and capacity. However, according to IEA, DG can be defined as an electrical source that is directly connected to the distribution network in order to supply and sustain the network to a local customer [2] and the size normally ranges from 50 MW up to 100 MW [3]. DG technologies can be grouped into two categories which are non-renewable DG sources and renewable DG sources. Diesel generator, micro turbines and fuel cell are the examples of non-renewable DG sources that are commonly being used. While solar photovoltaic (PV), wind turbine, hydro, geothermal, tidal and bio-fuel fall under renewable DG sources [4]. Renewable energy sources (RES) have, however, been the primary option in DG planning due to low generation costs and the degradation of centralized generation, which allows DG to be incorporated into the distribution system [5]. There are 4 types of DG technologies which can be described as follow [6]:

- Type 1 : Injects only active power (P) – for e.g. fuel cell and solar PV.
- Type 2 : Injects both active (P) and reactive power (Q) – for e.g. synchronous machine in gas turbine.
- Type 3 : Injects only reactive power (Q) – for e.g. synchronous compensator and capacitor bank.
- Type 4 : Injects active power (P) and consumes reactive power (Q) – for e.g. induction generator used in wind turbine.

The integration of DG from RES in distribution system provides a lot of benefits in terms of environmental, economic, technological, technical, and regulatory perspective. Through environmental perspective, the carbon dioxide emissions can be reduced with the integration of DG from RES. The cost of installation can be reduced in terms of economic benefits, since a DG unit is primarily deployed near the end user, thus minimizing the financial risk. Next, the expansion of small-scale development can be further developed from a technological perspective [7]. On the other hand, the technical benefits can be seen from real power losses minimization [8]

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and improvement on voltage profile, system reliability and power quality. In the event of unforeseen situations, such as sudden loss of power due to line outages, DG can act as a backup supply.

Although there are a lot of advantages to DG integration, excessive integration without proper planning can have a serious impact to the power system. In addition to affecting the stability of the grid and power quality, it can also result in voltage flicker, over voltages, excessive power losses, increased short circuit current [8] and a risk of out-of-phase reclosure that will damage the distribution system's adjacent loads and feeders [9]. Thus, a proper location, size, number of DG units and type of DG units must be taken into consideration during DG integration.

This concern has become one of the main interests for researchers to come out with a proper technique to find the best location and size of the DG unit to be integrated into the distribution network. There are many techniques that have been proposed in the literature for optimal placement of DG in distribution network which can be categorized into 3 groups: conventional techniques, metaheuristic techniques and hybrid techniques.

Some of the examples of conventional techniques are analytical techniques, exhaustive analysis, optimal power flow and probabilistic techniques [1]. All these conventional techniques have their own strengths such as computationally efficient, easy to be utilized and provide high accuracy solution. However, these techniques also have their own drawbacks such as computationally inefficient, need a lot of data and can affect the accuracy of the solution when working with complex problem [10].

The next technique available in literature is metaheuristic technique. This technique is based on iterative approach [11]. Some of the examples of metaheuristic technique are Genetic Algorithm (GA), Particle Swarm Optimization (PSO), Tabu Search (TS), Stimulated Annealing (SA) and Ant Colony Optimization (ACO) [1]. Despite these techniques can solve problem either with single or multi-objective function, they can also lead to premature convergence and can be trapped in local optima. The comprehensive reviews on these techniques have been presented in [1] and [7].

Due to all these drawbacks, many researchers have been combining these techniques, aiming to improve the quality of the solution and at the same time providing simplicity by reducing the search space and computational time [7]. These hybrid techniques have been utilized to find the solution of some decision variables such as DG sizing and location with various objectives such as power losses minimization, improvement on voltage profile and reliability, and cost minimization. However, the review on hybrid techniques for optimal placement of DG can hardly be found. Thus, this paper carries out a review of these hybrid techniques available in the literature for optimal placement of DG in distribution network by focusing on their performance involving various objectives.

The rest of this paper is organized as follows: Section 2 presents an overview on some of the conventional techniques for DG placement in distribution network. Section 3 presents an overview on some of the metaheuristic techniques available in the literature to solve optimal placement of DG. Section 4 provides review and comparative analysis of hybrid techniques available in the literature to solve optimal placement of DG by focusing on its objective and advantages. Finally, the conclusion is presented in section 5.

## II. Conventional Techniques

In this section, the conventional techniques for optimal DG placement are briefly discussed.

### *A. Analytical Techniques*

Analytical technique is a technique that applies the mathematical study in distribution system resulting in numerical equations and will be used as a tool to define the objective function [1]. This approach is often simple to implement and provides a converged outcome. Example of analytical technique available in literature is 2/3 rule [7]. Based on a simple rule, this technique applies approximation for capacitor placement in distribution system using graphical display of the power flow. Besides that, the loss sensitivity factor (LSF) and sensitivity analysis are also fall under analytical technique.

LSF technique helps to reduce the number of solutions needed by finding the sensitive node or line in distribution system. The computational time can be reduced as well, as shown in [7]. On the other hand, sensitivity analysis works by modifying certain parameters to observe how it will affect the outcome [12]. These two techniques have been successfully applied in [13] - [16] which had helped to reduce the search space and at the same time improve the computational time.

Besides the three techniques, there are other analytical techniques available in the literature that have been utilized in [17] - [21], where the aims are to minimize power losses and enhance voltage profile. In addition, the research in [10] applied this approach for multi-objective problem to find the optimal size of PV-type DG units, where, the objectives are to minimize the real and reactive power losses and voltage deviation. While it has short computational time, simplicity for implementation and strong convergence, the accuracy of the mentioned technique may be compromised when dealing with complex issues.

### *B. Exhaustive Analysis*

This technique has been used in [11] to mitigate losses in the distribution system. It works with a single objective function by thoroughly searching for all candidates of DG sizes and positions in the complete solution space. The research in [22] - [23] utilized this technique to solve multi-objective problem involving minimization of real and reactive power losses. This was done by finding the best location and size of the proposed DG units. The technique is computationally efficient when working with a single DG unit but may lead to computationally inefficient when working with multiple DG units with various load situations.

### *C. Mixed-integer linear/non-linear programming (MILP & MINLP)*

Both approaches are based on linear and non-linear optimization problem, which takes continuous and discrete variables into account [1]. MILP has become a commonly used technique for the optimization problem because it can provide an explicit solution. Research in [24] - [26] used MILP to boost the effect of the demand for DG reactive power on system's voltage and to increase the number of connected DG units in the system without sacrificing the voltage limit. This technique is sufficient for complex problems, but due to linearization, it may provide incorrect results.

MINLP, on the other hand, has been utilized in several researches as in [27] - [29] to optimally allocated DG units based on power loss sensitivity index. Research in [30] proposed this technique to reduce the power losses and to enhance voltage stability. Unlike MILP, this technique offers better accuracy but is rather difficult to be implemented due to the pre-condition of several variables.

### *D. Other conventional techniques*

Other conventional techniques that can be found in the literature are optimal power flow (OPF) and probabilistic technique.

OPF is usually used to solve non-linear programming and economic dispatch problem. However, this technique has also been used for optimal DG placement to reduce real power losses, as can be found in [31]. As the technique offers several advantages, either in terms of economic and technical aspects of distribution system, it has been widely implemented in DG allocation problem [7]. It also promises accurate results with better computational time. However, the involvement of closed formulation of parameters hinders its application.

Probabilistic technique, on the other hand, focuses on vague factor in DG planning such as electricity consumption [1]. This technique has been used in article [32] to enhance system's reliability and reduce the financial cost. In addition, the research in [33] applied the technique with multi-objective function to reduce the cost and emission of pollutant. However, this technique requires massive size of data. Table 1 provides the summary of the conventional techniques discussed throughout this section.

TABLE I. SUMMARY OF CONVENTIONAL TECHNIQUES USED TO SOLVE DG PLACEMENT AND SIZING PROBLEM

| Conventional Technique | Strengths | Weaknesses |
|---|---|---|
| Analytical Technique | • Simple to implement and provides a converged outcome.<br>• LSF - reduce the computational time.<br>• Sensitivity analysis - reduce the search space and at the same time improve the computational time. | • The accuracy of the outcome may be compromised when dealing with complex issues. |
| Exhaustive Analysis | • Computationally efficient when working with a single DG unit | • May lead to computationally inefficient when working with multiple DG with various load generation. |
| Mixed-integer linear/non-linear programming (MILP & MINLP) | • MILP - sufficient for complex problems<br>• MINLP - offers better accuracy | • MILP - due to linearization, it can provide incorrect results.<br>• MINLP - not easy to be implemented due to the pre-condition of several variables |
| Other conventional techniques | • OPF - promise accurate result with better computational time.<br>• Probabilistic technique – Efficient in modelling intermittent generation and accessibility of renewable DG | • OPF - closed formulation of parameters are involved which hinder its usage.<br>• Probabilistic technique – Required immense of data. |

## III. METAHEURISTICS TECHNIQUES

Metaheuristic techniques have become the most implemented techniques due to their effectiveness and simplicity to solve the optimal DG placement and sizing problem in distribution network. These techniques do not require pre-condition on the objective function and constraints, thus, become a popular technique to be used. In this section, several mostly used metaheuristic techniques are discussed.

### *A. Genetic Algorithm (GA)*

Development of GA is based on genetic concepts which includes selection, crossover, mutation, and inheritance [1]. This technique has been utilized by research in [34] and [35] to minimize the line losses, voltage deviation and cost. In [36], non-dominated sorting genetic algorithm (NGSA II) has been proposed with the objective to minimize the investment, operation and maintenance cost. When applying with a multi-objective function, GA has proven to be sufficient. However, when working with large systems, premature convergence can occur.

### *B. Particle Swarm Optimization (PSO)*

PSO was developed to mimic the behavior of birds' flocks. Research in [37] proposed this technique to find the best DG units and static compensator's location and size in order to minimize losses and to enhance voltage profile. In [38] and [39], PSO has been utilized to minimize the Total Harmonic Distortion (THD), losses, cost and enhance the voltage profile. With fewer iteration numbers needed as compared to GA, PSO has proven to be a better solution. It also needs less computational time than GA. However, as in GA, PSO may also stuck in local optima when working with complicated problems.

### *C. Tabu Search (TS)*

The theory of adaptive memory and sensitive exploration motivate the development of TS, allowing the solution space to be searched economically and efficiently until no progress is achieved [7]. In [40] and [41], this technique was used for optimal DG location to minimize losses and line loadings. In [42] TS was used to study the effect of electric vehicles on the distribution system with a view to reduce operating costs. TS has several advantages of working with complex problem and suitable to be used with discrete and continuous variables

### *D. Ant Colony Optimization (ACO)*

This technique was inspired by the social behavior of ant foraging for food. Research in [43] and [44] proposed ACO to find the optimal DG location and size with objective of reducing the power losses. While in [45], this technique was implemented with hybrid system to minimize the cost and improve the system's reliability. As compared to GA, PSO and TS, this approach does not face problem with premature convergence and offers quicker solutions. However, the time of convergence can be uncertain, and the performance is likely to change with each iteration.

### *E. Other metaheuristic techniques*

Apart from GA, PSO, TS and ACO, there are many more metaheuristic techniques that are available in the literature. Some of the techniques that are not being discussed here are: Cuckoo Search Algorithm (CSA) [46], [47], Firefly Algorithm (FA) [48], [49] Stimulated Annealing (SA) [50], [51], Harmony Search (HS) [52]– [54] and Bat Algorithm (BA) [55]. Table 2 provides the summary of the metaheuristic techniques discussed throughout this section.

TABLE II. SUMMARY OF METAHEURISTIC TECHNIQUES USED TO SOLVE DG PLACEMENT AND SIZING PROBLEM

| Metaheuristic Technique | Strengths | Weaknesses |
|---|---|---|
| Genetic Algorithm (GA) | • Sufficient when working with multi-objective function.<br>• Do not require derivatives | • Premature convergence can occur when working with large systems. |
| Particle Swarm Optimization (PSO) | • Fewer iteration numbers needed compared to GA.<br>• Proved to have a better solution | • Premature convergence<br>• May stuck in local optima when working with complicated problems |
| Tabu Search (TS) | • Advantage of working with complex problem<br>• suitable to be used with discrete and continuous variable | • There is a chance for the solution to be trapped in local optima as in GA and PSO. |
| Ant Colony Optimization (ACO) | • Does not face problems with convergence.<br>• Offers quicker solutions | • The time of convergence can be uncertain.<br>• The distribution is likely to change with each iteration. |

## IV. HYBRID TECHNIQUES

In order to eliminate some of the drawbacks from the conventional and metaheuristic techniques, researchers have tried to hybridize them. These hybrid techniques can be either a hybrid between conventional and metaheuristic or between metaheuristic technique itself. By combining these techniques, the solution can be improved, provides simplicity, and scale down the search space. In this section, two types of hybrid technique, namely the conventional-metaheuristic hybrid and metaheuristic hybrid are discussed.

### *A. Conventional – Metaheuristic Hybrid*

This section discusses the techniques that have been hybridized between conventional and metaheuristic techniques. Research in [56] has proposed a hybrid technique between voltage stability index (VSI) and sine-cosine algorithm (SCA) to find the best location and size of DG unit and static compensator in distribution system to minimize the power losses.

The VSI was utilized to find the most suitable locations in order to integrate the DG unit and static compensator, while the SCA was used to determine the best size of both devices. The identification of suitable buses in the system becomes easier when using VSI, where bus with the highest stability index is chosen as the best location for DG placement. The result showed an improvement in terms of power losses as compared to other techniques.

While in [57], the Loss Sensitivity Factor (LSF) was hybridized with Particle Swarm Optimization and Gravitational Search Algorithm (PSOGSA) for multi objective problem, where the aims were to minimize the power losses and cost and at the same time to enhance voltage stability. Like VSI, the LSF was used to find the suitable locations for placement of DG units. Through this implementation, the search space will be reduced and PSOGSA was utilized to find the optimal size of DG units. The result from the proposed technique showed an improvement in terms of power loss, cost and voltage stability.

Article [58] has proposed a hybrid technique which combines OPF with the Improved Harmony Search (IHS). The main objective is to reduce the losses by searching the optimal size and location of DG units. IHS was used to find the best DG location while OPF was utilized to determine the DG size. The proposed technique also considered single and multiple DG placement in order to observe the performance and robustness of the approach. The hybridization of IHS with OPF is to reduce the search space with less control parameters. The result showed faster convergence with improved solution as compared to other techniques. However, there is still a chance for the technique to stuck in local optima.

In [59], hybrid GA and OPF has been proposed in order to find the optimal location and sizing to reduce the cost of active and reactive power generation. In the research, GA has been utilized to find the best location for DG placement, while OPF was used for DG sizing. The proposed approach successfully results in reduction of financial cost.

Research in [16] has proposed a hybrid technique between sensitivity analysis and Evolutionary Programming (EP) for optimal placement of DG in 69-bus distribution system, where the aims were to minimize the losses and to enhance voltage profile. Sensitivity analysis was utilized in order to find the most sensitivity bus which will be chosen as candidate bus for DG installation. The result showed that the proposed technique required a smaller number of generations to converge and also computationally efficient as compared to GA and Exhaustive Search technique. This shows that by implementing the sensitivity analysis, the search space can be reduced and at the same time, reduce the possibilities for the algorithm to be trapped in local optima. In addition, the losses have been minimized and voltage profile was improved as well.

Research in [60] has proposed a hybrid technique between PSO and analytical approach based on mathematical procedure as proposed in [61]. The analytical approach was used to find the optimal size of DG units, while PSO was used to search for optimal locations. This hybrid approach aims to minimize the power losses. The proposed technique has been applied in 33-bus and 69-bus distribution system with multiple DG installation. The result showed that it did minimize the power losses when the systems were installed with multiple DG units. In addition, the size of the DG units has shown some reduction without jeopardizing the voltage limits.

### *B. Metaheuristic Hybrid*

Beside conventional-metaheuristic hybrid technique, different metaheuristic algorithms can also be hybridized together to produce a different version of hybrid algorithm. Research in [62] proposed a hybrid technique between EP and PSO which is known as Rank Evolutionary Particle Swarm Optimization (REPSO) to optimize the output of multiple DG units. In the research, the locations of DG are fixed and not being treated as optimization problem. The result showed that the proposed method provided much simpler process to achieve global best solution. In addition, the copper losses were also minimized. The performance of the proposed technique is better than Conventional Particle Swarm Optimization (CPSO), and a smaller number of iterations is required with faster computational time than Inertia Weight Particle Swarm Optimization (IWPSO) and Iteration Particle Swarm Optimization (IPSO).

Article [63] has proposed a hybrid technique between Harmony Search Algorithm (HSA) and Particle Artificial Bee Colony algorithm (PABC) to search for the best location and size of DG and shunt capacitor, which aimed to minimize the power losses and improve the voltage profile in distribution system. The research used two approaches; first, utilizing the loss sensitivity factor to find the sensitive node for DG placement and followed by implementing the proposed hybrid technique for DG sizing. Second, utilizing the hybrid technique to determine both the size and location for DG placement. The hybridization of these two techniques was performed in order to overcome the drawbacks of slow convergence and premature convergence resulted from HSA. The second approach provided significant power losses minimization and voltage profile enhancement with improved convergence and computationally efficient.

Research in [64] proposed a hybrid technique between Teaching Learning Based Optimization (TLBO) with mutation from Differential Evolution (DE) in order to find the best location and size of DG units. Determination of DG location and sizing was done by treating these decision variables as optimization problem and utilized the technique to find the optimal location and size of DG. The performance of the proposed technique did show an improvement in terms of acceptable solution with lower computational cost than exhaustive technique. In addition, it also showed an equal or better performance as compared to other techniques available in the literature.

Next, research in [65] proposed a technique which combines fuzzy system with PSO to reduce the power losses in distribution system without risking the voltage limit. The research utilized the fuzzy system to find the optimal location for DG placement while the PSO was used to determine the optimal size of the DG. The performance of the proposed technique was compared with analytical technique and another hybrid technique which combined the fuzzy system with GA technique. The power losses have been minimized significantly by using the hybrid technique, and it was better than analytical approach. Furthermore, the hybrid technique between fuzzy and PSO provided better performance as compared to another hybrid technique with GA in terms of power losses and computational time.

In article [66], a hybrid technique between Imperialist Competitive Algorithm (ICA) and GA has been proposed to solve multi-objective function by determining the optimal location and size of DG units and shunt capacitor. The optimization process has been done simultaneously to find the best location and size of both DG and shunt capacitor. The proposed technique proved to be a better option which minimized the power losses significantly. Besides that, the voltage profile and voltage stability index have been mitigated, while the load balancing and economic cost have been properly improved as well. In addition, it is found that its performance has outperformed GA and PSO technique.

Afterwards, research in [67] proposed a hybrid technique between ACO and Artificial Bee Colony (ABC) for optimal placement and sizing of DG in distribution system, with objectives of reducing power losses, emission produced, total cost and at the same time enhance voltage stability. ACO was utilized to find the optimal location of DG while ABC was implemented to determine the optimal sizing of DG. Result from the proposed technique showed a reduction in power losses and provided a better performance compared to other techniques, especially when multiple DG units were being considered.

In [68], hybrid technique between binary particle swarm optimization and shuffled frog leap (BPSO-SLFA) algorithm has been proposed to minimize losses and enhance voltage stability in distribution system by determining the optimal location and size of DG. The proposed technique has been tested in 33-bus and 69-bus radial distribution system and the result showed a significant reduction in power losses as well as enhancement in voltage profile. The performance of the technique has also outperformed other hybrid techniques such as Hybrid Grey Wolf Optimization (GWO) and Hybrid Big Bang Big Crunch.

The summary of hybrid techniques discussed throughout this section is presented in Table 3. Besides all the hybrid techniques mentioned here, there are still many articles available in the literature that deal with new hybrid techniques and algorithms.

TABLE III.SUMMARY OF HYBRID TECHNIQUES USED TO SOLVE DG PLACEMENT AND SIZING PROBLEM

| Hybrid Category | Optimization Technique | Decision Variable(s) | Objective Function | Main Findings |
|---|---|---|---|---|
| Conventional – Metaheuristic hybrid | VSI-SCA [56] | DG and static compensator size and location | Minimize power losses | • VSI utilized to find the best bus location.<br>• SCA was used to determine the best size.<br>• Reduce power losses.<br>• Show better performance compared to other techniques |
| | LSF – PSOGSA [57] | DG size and location | Minimize power losses, cost, and improve voltage stability | • LSF is used to find the best bus location.<br>• PSOGSA is utilized to find the optimal size of DG.<br>• Reduce power losses and cost.<br>• Improve voltage stability.<br>• Reduce search space |
| | OPF – IHS [58] | DG size and location | Minimize power losses | • IHS used to find the best DG location.<br>• OPF was utilized to determine the DG size.<br>• Faster convergence with improved solution compared to others technique.<br>• Have a chance for the solution to stuck in local optima. |
| | GA – OPF [59] | DG size and location | Minimized cost, real, and reactive power generation | • GA used to find the best DG location.<br>• OPF was utilized to determine the DG size.<br>• Economic cost reduction can be achieved. |
| | Sensitivity analysis – EP [16] | DG location | Minimize real power losses and improve voltage profile | • Sensitivity analysis is used to find the most sensitivity bus.<br>• Less number of generations to converge.<br>• Computationally efficient as compared to GA and Exhaustive Search technique.<br>• Search space can be reduced and at the same time reduce the possibilities for the solution to be trapped in local optima.<br>• Losses have been minimized and voltage profile was improved. |
| | PSO – Analytical [60] | DG size and location | Minimize power losses | • Analytical is used for DG sizing.<br>• PSO is used for DG location.<br>• Power losses was minimized when install with multiple DG with proper size.<br>• Size of DG also show some reduction with implementation of the proposed technique without jeopardize the voltage limits. |

| | | | | |
|---|---|---|---|---|
| | REPSO [62] | DG size | Optimize the output of multiple DG | • Location of DG is fixed.<br>• EP was utilized to simplify PSO.<br>• Simpler process to achieve $P_{best}$ and $G_{best}$.<br>• Copper losses also is minimized.<br>• The performance of the proposed CPSO.<br>• Less number of iterations is required with better computational compared to IWPSO and IPSO. |
| | HSA – PABC [63] | DG and shunt capacitor size and location | Minimize power losses and improve the voltage profile | • 1st approach – utilized LSF for DG location and hybrid technique for DG sizing.<br>• 2nd approach – utilized hybrid technique for both DG location and sizing.<br>• Power losses is minimized significantly using 2nd approach.<br>• Voltage profile is improved.<br>• Computationally efficient. |
| | TLBO – DE [64] | DG size and location | Minimize power losses | • Show improvement in terms of acceptable solution with lower computational cost compared to exhaustive technique.<br>• Show equal or better performance compared to other technique available in literature. |
| Metaheuristic hybrid | Fuzzy – PSO [65] | DG size and location | Minimize power losses without jeopardize the voltage limit | • Utilize fuzzy system to find the optimal location for DG placement.<br>• PSO is used to determine the optimal size of the DG.<br>• Power losses has been minimized significantly.<br>• Provide better performance compared to hybrid technique with GA in terms of power losses with better computational time. |
| | ICA – GA [66] | DG and shunt capacitor size and location | Solve multi objective function | • Minimize the power losses significantly.<br>• Voltage profile has been improved, increase voltage stability index, and load balancing and reduce the economic cost.<br>• Outperformed GA/PSO technique. |
| | ACO – ABC [67] | DG size and location | Minimize power losses, emission produced, total cost and enhance voltage stability. | • Utilized ACO for optimal location of DG.<br>• ABC is used to find the DG optimal sizing.<br>• Reduction in power losses<br>• Better performance compared to other techniques when multiple DGs are being consider. |
| | BPSO-SLFA [68] | DG size and location | Minimize power losses and enhance voltage stability | • Significant reduction of power losses and enhancement in voltage profile.<br>• Outperformed other hybrid technique such as Hybrid GWO and Hybrid big bang big crunch. |

## V. CONCLUSION

This paper presents a review on hybrid techniques for optimal DG placement in distribution network. Hybrid technique is a technique that combines two or more different techniques in order to improve and eliminate some of the drawbacks that resulted from individual techniques. These hybrid techniques are classified into two categories: conventional-metaheuristic hybrid and metaheuristic hybrid. Each of the category has been discussed with some of the examples from the literature related to the technique implementation, the decision variables involve, various objectives and their outcomes. Important findings from this review show that the hybrid technique has been widely implemented in DG placement problem considering various objectives, such as minimizing power losses, improving voltage stability as well as cost. The major advantage of using hybrid techniques is that the search space and computational time can be reduced significantly. This technique also offers a better performance as compared to the individual ones. For future works, it should be more hybrid techniques proposed since there are many other techniques available out there which are not fully explored for hybrid purposes.

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