OPTIMAL LOCATION AND SIZING OF DISTRIBUTED GENERATION: A REVIEW OF THE STATE OF THE ART

Daniel Camilo Londoño Tamayo[1], Pablo A. Narváez Burgos[2], Jesús María López Lezama[3]

[1]Electrical Engineer, Universidad de Antioquia.
[2]Masters Student, Universidad de Antioquia, Substation Engineering Analyst at Interconexión Eléctrica S.A, Calle 12 sur No 18-168, Medellín, Colombia.
[3]Ph.D. in Electrical Engineering, Grupo GIMEL, Department of Electrical Engineering, Universidad de Antioquia UdeA, Calle 70 No 52-21, Medellín, Colombia. E-mail: jesusmarialopezl@gmail.com

ABSTRACT

Distributed generation (DG) has gained great interest from the electric industry in recent years. Currently, the presence of DG is increasingly common in distribution networks. This has motivated the exploration of different methodologies for its proper location and sizing, in order to harvest its potential benefits. A review of the state of the art regarding location and sizing of DG in electric power systems is presented. The methodologies that are usually applied for this aim are classified in five main groups: i) analytical, ii) heuristic, iii) meta-heuristic, iv) hybrid, and v) mathematical programming. These methodologies (used to determine the optimal location of DG, its optimal sizing, or both) are presented and discussed.

Keywords: distributed generation (DG), location, sizing, optimization

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UBICACIÓN Y DIMENSIONAMIENTO ÓPTIMO DE GENERACIÓN DISTRIBUIDA: UNA REVISIÓN DEL ESTADO DEL ARTE

RESUMEN

La generación distribuida (GD) ha cobrado gran interés en la industria eléctrica en los últimos años. En la actualidad, es cada vez más común la presencia de DG en las redes de distribución. Esto ha motivado la exploración de diferentes metodologías para su correcta ubicación y dimensionamiento en aras de aprovechar sus beneficios potenciales. En este artículo se presenta una revisión del estado del arte en el tema de ubicación y dimensionamiento de DG en sistemas de energía eléctrica. Las metodologías utilizadas para este objetivo se han agrupado en cinco grupos principales: i) Analíticas, ii) Heurísticas, iii) Metaheurísticas, iv) Híbridas y v) Programación Matemática. A lo largo del documento estas metodologías (utilizadas para encontrar la ubicación óptima de la DG, su dimensionamiento o ambas cosas) son presentadas y discutidas.

Palabras clave: *generación distribuida, ubicación, dimensionamiento, optimización.*

1. INTRODUCTION

Distributed Generation (DG) can be defined as the production of electricity on a small scale, either in a distribution network or near the final consumers [1]. The resources that are used by DG can be classified as renewable or non-renewable. The DG technologies that involve renewable resources include wind power production, solar photovoltaic production, and production with the use of biomass. The technologies that use non-renewable resources include internal combustion engines, micro-turbines and combustion cells. In the past few years, DG has gained a lot of importance due to several factors:

- The liberation of the electric sector, with the subsequent introduction of competing agents in terms of the generation and commercialization of energy.
- The new trends in smart grids, where demand is participating actively.
- New environmental policies to promote the use of renewable resources and the efficient use of energy.
- Environmental restrictions for the construction of new transmission lines.
- New technologies for the efficient small-scale production of electricity.

Due to these factors, the presence of DG has become increasingly common in distribution networks. However, these networks were not designed to function with DG, meaning that the insertion of DG in the network must be carefully planned out. The integration of DG in distribution networks has become the focus of many studies in the past decade. A large part of these studies focus on its optimal location and sizing. There are different objectives that can be sought after in the DG planning process; these objectives include the reduction of losses, the improvement of voltage profiles, the increase in reliability, network investment deferral, etc. Different models and solutions have been proposed to attain these objectives. This article presents a bibliographical revision of the different methods that are used for the location and/or sizing of DG. The solutions have been classified in 5 main groups: a) analytical methods, b) heuristic methods, c) meta-heuristic methods, d) hybrid methods, and e) methods based on mathematical programming.

2. ANALYTICAL METHODS FOR THE LOCATION AND SIZING OF DG

The analytical methods described in this section seek to deduce a mathematical expression that can be used to determine the appropriate location and/or sizing of DG with a specific purpose in mind. These methods are easily implemented and can be speedily executed. However, their results are only indicative, because obtaining analytical expressions requires the use of presumptions that fail to consider the network's real complexity. One of the most common objectives in the location of DG is the reduction of losses, as can be observed in [2]. This reference integrates voltage and loss differentials throughout a line to calculate total voltage drops and power losses. The authors consider different load distributions and deduce the analytical expressions to determine the location of the DG that reduces losses. The authors consider three types of demand distributions: uniform, centrally distributed and incrementally distributed (see Fig. 1). The main drawback of this method is that real systems exhibit a demand pattern that usually does not adjust to the described patterns.

In reference [3], an algorithm is proposed based on an analytical approach to determine the optimal location for DG in a radial distribution feeder. The objective is to reduce losses and improve the voltage profile. For this purpose, a voltage profile index relating voltage with and without DG is used. Reference [4] presents analytical expressions that allow the determination of the limit of the power that can be injected into a node in the network without incurring in overpowering. These expressions enable the determination of the appropriate sizing of the DG given its specific location. The authors consider both grouped and distributed loads, and examine the effect of DG on the power losses for both cases in low-voltage systems.

Reference [5] further develops analytical methods that aim to establish the maximum limit of the DG, which could be installed in a node, without surpassing the harmonic limits established by regulations. The most limiting harmonics are also established, as well as the impact that the positive, negative, and zero sequence harmonics have. Additionally, equations are formulated exactly for typical DG supply designs, and different load patterns are considered.

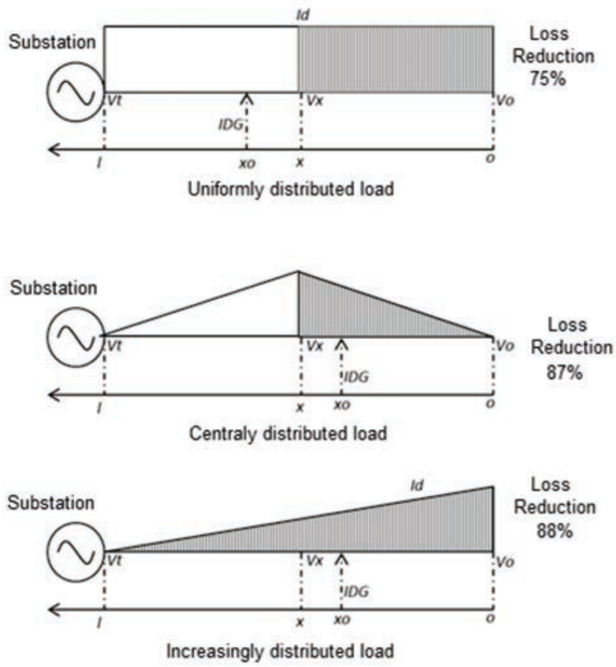

Fig. 1. Types of demand distribution considered in [2] and corresponding loss reduction.

Reference [6] presents a method for the optimal location of the DG with the purpose of reducing losses. Such method uses the equivalent of current injection, avoiding the use of an admittance matrix, its opposite, or the Jacobean. Reference [7] uses an analytical expression based on the exact power loss formula to determine the appropriate size of the DG to reduce power losses. The authors thoroughly examine the effect of the location and sizing of the DG with respect to system losses. The results are compared with exhaustive load flow methods and sensibility analyses.

Reference [8] deduces analytical expressions to determine, not just the size, but the power factor of the DG to minimize power losses. In this case, the authors use an approximate formula for the losses.

Table 1 summarizes the aspects that were considered in the location and sizing of the DG in the analytical methods described in this section. In this case, L corresponds to Location and S corresponds to Sizing.

Comparing analytical methods to locate and size DG is complex, as each author uses different proof systems and approximations (that may be more or less strict) to the load flow equations.

Table 1. Aspects that are considered in the location and sizing of DG (analytical methods).

Ref	***Variable***		***Objectives***
	L	**S**	
[2]	x		Reduce losses
[3]	x	x	Improve voltage profile and reduce power losses
[4]		x	Maximize the penetration of DG without incurring in overpowering
[5]	x	x	Maximize the level of penetration of the DG considering harmonics
[6]	x	x	Minimize power losses.
[7]	x		Minimize power losses in a primary distribution network
[8]	x		Minimize power losses

For example, reference [2] uses a general network and doesn't consider reactive current, and reference [6] uses a 6-bar system and considers both active and reactive power. On the other hand, reference [5] uses a 34-bar three-phase proof system, while reference [7] uses 27-bar, 30-bar, and 69-bar single-phase systems. However, regardless of the variety of models and the level of detail in the calculations, these methods all search for concrete mathematical expressions that may determine the system losses exactly or approximately in relation to the presence of DG. The common difficulty in these methods is that they use approximations to the load flow and fail to express the real complexity of the network.

3. HEURISTIC METHODS FOR LOCATION AND SIZING OF DG

Heuristic methods are algorithms designed to identify solutions and good candidates for problems with a high degree of difficulty. This types of methods are easily implemented, and enable the selection of candidates by using relatively small computing methods. They are usually designed taking into account the particularities of the specific problem, and attempt to take the most advantage of them. However, due to their nature, they are often trapped in local optimums, and they fail to obtain global solutions to a problem.

The applications used to locate and size DG in distribution networks by means of heuristic methods are based on an iterative procedure in which the state of the network is verified in every iteration according to the load flow. Such procedure is usually intuitive or based on experience, and it seeks to continually improve one or several previously defined indexes. Fig. 2 illustrates a general flowchart for the application of a heuristic method like the ones described in this section.

Reference [9] seeks to locate DG in the most appropriate way using an iterative algorithm based on a continuing power flow. The proposed method allows the increase of both the power transfer capacity and the voltage stability margin. In [10] the authors propose a similar study that seeks to increase the network's chargeability. In each iteration, the first node to reach the voltage limit is identified; then, DG is installed in this node, and a continuing power flow is carried out. The objective of this methodology is to increase the network's chargeability. Reference [11] proposes a method for the appropriate location of DG, seeking to optimize efficiency and reliability considering the demand variations in time. [12] presents a heuristic method for the optimal location of DG according to the optimal power flow. In this case, two different objectives are analyzed separately: the maximization of the net social benefit, and the maximization of profit. The buses that are candidate for the location of DG are determined using two indexes: the marginal prices (obtained from the optimal flow) and the payment of consumers.

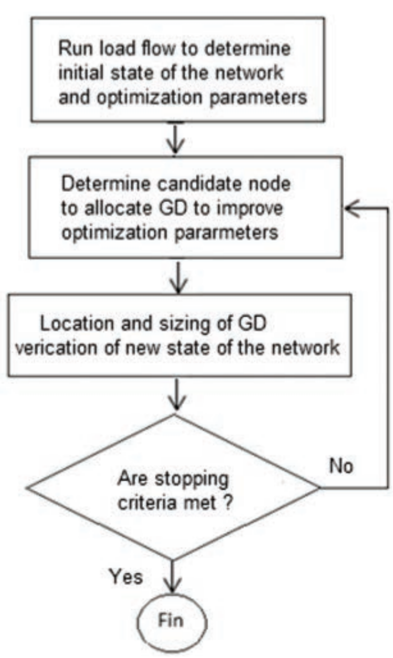

Fig. 2. General diagram to locate and size DG using a heuristic method.

The sizing of the DG is determined by varying the DG located on a particular node incrementally.

Reference [13] presents a methodology that considers the evolution of the generation and load in time, taking into account two stages of calculation. The external stage selects a group of candidate nodes using an approach based on loss sensibility factors. The internal stage conducts an exhaustive search to calculate the function, aiming to minimize energy losses and improve the voltage profile. In [14] the authors use voltage sensibilities to determine the maximum level of power that can be injected by the DG for each bar in the system without violating the stable voltage levels. Reference [15] sets forth a heuristic method for the location and sizing of the DG. In this case, special attention was given to the vision of the planner with respects to the election of appropriate weight factors considering the levels of short-circuit, losses, and voltage profiles.

Reference [16] uses a conventional iterative search technique, combined with Newton Raphson's power flow method, to determine the location and size of the DG, aiming to minimize costs and power losses. Reference [17] sets forth an heuristic method that uses increasing long-term costs to identify the size and location of the DG, seeking to increase the economic potential from a social benefit perspective. In [18] the authors present an algorithm to determine the optimal location of multiple DG units. The aim is to broaden the stability margins and reduce power losses. Reference [19] proposes a heuristic method that approaches the location and the sizing of the DG as two independent sub-problems. The method described in this article is applied to a radial system, and seeks to minimize power losses. In [20] the authors offer an heuristic approach to the planning process of DG, from the perspective of the distribution company, which seeks to reduce the costs of investments and minimize power losses. The approach offers a cost-benefit analysis, presenting a DG investment plan for a competitive electricity market and for fixed scenarios of bilateral contracts. Table 2 summarizes the aspects that are considered for the location and sizing of the DG in the heuristic methods described in this sections. In this case, L corresponds to Location and S corresponds to Sizing.

Table 2. Aspects that are considered in the location and sizing of DG (heuristic methods).

Ref	***Variable***		***Objectives***
	L	**S**	
[9]	x		Improve voltage stability
[10]	x	x	Maximize network chargeability
[11]	x		Maximize network efficiency and reliability
[12]	x		Maximize profit and social benefits
[13]		x	Minimize energy losses
[14]		x	Maximize the power level that can be injected by the DG.
[15]	x	x	Minimize losses, improve voltage levels and short-circuit currents
[16]	x	x	Minimize costs and power losses
[17]	x	x	Maximize social benefits
[18]	x		Minimize power losses
[19]	x	x	Minimize power losses
[20]	x	x	Minimize power losses

As can be observed in this section, the objectives that are pursued in the location and sizing of the DG are not limited to the reduction of power losses, as could be observed in the analytical methods. In this case, new objectives are considered, such as the maximization of net social benefits, the maximization of network chargeability, and the improvement of reliability.

4. META-HEURISTIC METHODS FOR LOCATION AND SIZING OF DG

Meta-heuristic methods are algorithms that add a stochasticity factor to the solutions they find. In general, they are not based on a greedy search for solutions, thus allowing them to accept temporary solutions that go against the improvement of the solution. This allows them to explore the search space more exhaustively in their quest to find a better solution, which, in some cases, would coincide with the global optimum. They are generally inspired in analogies with physics, biology and ethology. They have the same difficulties: the requirement of an intrinsic parameter adjustment to be more accurate and adapt their techniques better to the problem that they have to solve. This is why they are generally known as techniques that do not depend on the problem, and they don't take advantage of the problem's particularities, using them as black boxes.

This section describes the main meta-heuristic methods applied in the determination of the location and/or sizing of the DG. Within these applications, the use of genetic algorithms and Particle Swarm Optimization should be emphasized.

A genetic algorithm displays a method that simulates the principle of natural selection and survival of the fittest within species. In this case, a group of individuals that should "evolve" is created. This evolution occurs thanks to genetic operators for selection, to recombination, and to mutation. In each iteration, the most suitable solutions have a better chance of generating new solutions in the next generation. Fig. 3 illustrates a flowchart of the process that the genetic algorithm follows.

Particle Swarm Optimization is a technique that simulates a swarm of insects where agents or particles cover the space of the problem. Each of them has the objective of searching for an appropriate position or a good solution, communicating amongst themselves, guiding the search towards the agent with the best position.

The bee colony algorithm offers a simile to the search for sustenance that a beehive requires. It bases its principle on the interaction between bees that have a common position and between the nearest source of sustenance to identify an adequate candidate.

To implement a meta-heuristic pertaining to the location and sizing of the DG, it is necessary to code the possible solutions to the problem. Typical codifications can be binary or integer. Fig. 4 illustrates a 13-bus system with three DG units located on buses 4, 7, and 13. A possible codification consists of generating a vector with 13 positions, and assigning a number one (1) to the corresponding index where the generator is located, as illustrated in Fig. 5. However, this type of codification makes it possible to consider the location of the DG, but not its size.

Fig. 6 illustrates an alternative configuration that may consider the location and the size of the DG units. In this case, two vectors are used, the top one indicates the location of the DG unit, and the bottom one indicates its size.

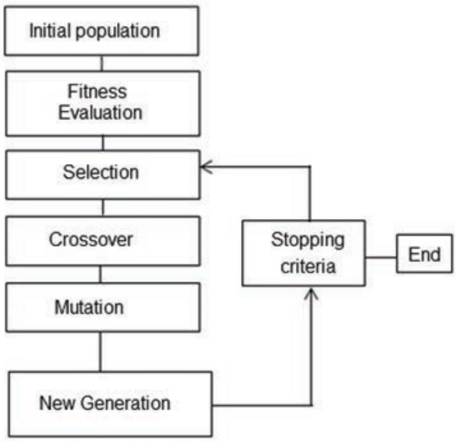

Fig. 3. Flowchart of a GA.

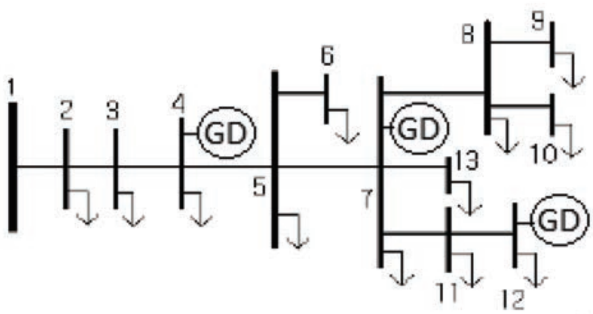

Fig. 4. 13-bar distribution system with three DG units.

0	0	0	1	0	0	1	0	0	0	0	1	0

Fig. 5. Possible codification to represent the location of the DG units.

0	0	0	1	0	0	1	0	0	0	0	1	0
0	0	0	T4	0	0	T7	0	0	0	0	T12	0

Fig. 6. Possible codification to represent location and size of DG units.

Bus 1	Bus 2	…..	Bus 7	…..	Bus 13
0100	0011	……	1011	…..	0010

Fig. 7. Alternative codification to represent location and size of DG units.

Fig 7 illustrates another codification alternative that uses binary numbers. If the first digit is zero, it indicates that the DG is not located on that bus, and if the first digit is one, it indicates that there is DG in that bus. The other digits can be used to code the size of the DG. For example, in buses 1 and 2 there is no DG (the first digit is zero), but there is DG in bus 7, and its size is coded with the binary digit 011.

One of the advantages of meta-heuristic optimization techniques is that they can adapt to problems with multiple objectives. Reference [21] showcases a multipurpose approach that models a distribution system where the system is reconfigured to locate the DG, minimizing energy losses in the new topology. In [22] the authors developed a multi-objective approach to determine the best location for DG, taking into account losses, voltage profiles, and the chargeability limit. Reference [23] offers a meta-heuristic algorithm called the Cuckoo Search, which coordinates the power transmitted by the DG units. The aim of the algorithm is to improve the active power transference of the generators. [24] determines the location and price of the contract considering DG technologies that can be dispatched, and its approach is based on a two-level programming framework that correlates the interests of the DG owner and the distribution company. In this case, an action-reaction game is considered, where the DG owner makes a decision about the location and the prices for energy sales, and the network operator reacts to this decision by buying either more or less energy in terms of an optimal dispatch.

Reference [25] studies the location of DG in relation to protective devices for a determined DG capacity, seeking to improve reliability. [26] and [27] present a meta-heuristic method known as Particle Swarm Optimization (PSO). The study in [26] includes different charging models in a distribution system with non-unitary power factor. In this case, the aim is to reduce losses and improve the voltage profile, taking into account the capacity limits of the network and the short-circuit levels of the protection devices. In [27] the authors seek to minimize the cost of fuel, power losses, and to improve the voltage profile.

In references [28] to [32], the location and sizing of the DG is optimized by using genetic algorithms. The method proposed in [28] allows the planner to decide the best location for DG, considering economic criteria. In [29] the authors present a DG approach related to the remotely controlled protections for an annual multilevel charging model. [30] uses a stochastic algorithm for the appropriate location of DG, bearing in mind technical (voltage sags and losses) and economic factors. Reference [31] studies multipurpose performance indexes in distribution systems with different load models to locate and size the DG. In [32] the authors suggest a function that uses genetic algorithms to handle the relationship between the benefit of installing

DG, and the required investment and operation costs of the installation.

Reference [33] uses Artificial Bee Colony (ABC) algorithms to determine the location and sizing of DG to minimize active losses in the network. In [34] the authors offer an imperialist competitive algorithm (ICA) that determines the optimal location and sizing of the DG to reduce power losses and defer investments in new networks.

Reference [35] uses a meta-heuristic method that is based on frog leap dynamics (*shuffle frog leaping algorithm*) to locate and size the DG, with the purpose of minimizing losses and costs of the DG.

In [36] the authors developed a multipurpose dynamic model to determine the location, sizing and optimal time investment of the DG and other components of the network. In this case, technical constraints, costs and contaminating emissions are taken into account. The model considers load uncertainties, the cost of electricity and wind generation. [37] uses an immune algorithm for the solution of a dynamic model in different periods, considering load increase. Environmental and economic criteria are taken into account to determine the location and sizing of the DG. Reference [38] studies the optimal sizing of the DG with genetic algorithms, reflecting on the use of renewable energy sources and power storage systems with the objective of reducing the cost of the investments in the network. In [39] the authors propose a dual genetic algorithm to evaluate the maximum capacity that can be admitted in distribution generators connected to the distribution network. Table 3 summarizes the aspects that are considered in the location and sizing of DG by the meta-heuristic methods covered in this section. In this case, L corresponds to Location and S to Sizing.

It can be observed that when meta-heuristic techniques are applied to the location and sizing of the DG, it is possible to consider different objectives and even several objectives simultaneously. Some of the main and most common objectives are: the minimization of losses, the improvement of the voltage profile, the minimization of resources, and the minimization of emissions, among others.

Table 3. Aspects that are considered in the location and sizing of DG (meta-heuristic methods).

Ref	***Variables***		***Objectives***
	L	**S**	
[21]	x		Minimize losses
[22]	x		Minimize losses and improve the voltage profile
[23]		x	Maximize active power transfer
[24]	x		Maximize income resulting from selling the DG power
[25]	x		Maximize reliability
[26]	x	x	Minimize losses and improve the voltage profile
[27]		x	Minimize the cost of combustible, the power losses and improve the voltage profile
[28]	x	x	Minimize economic costs
[29]	x	x	Minimize the losses in the distribution network
[30]	x	x	Minimize the effect of power holes and reduce losses
[31]	x	x	Minimize active and reactive losses, improve voltage levels and reduce congestion
[32]	x	x	Propose a function that handles the relationship between the benefit of installing DG and the cost of the investment
[33]	x	x	Minimize the active losses of the network
[34]	x	x	Minimize the power losses and postpone investment in new networks
[35]	x	x	Minimize losses and cost of the DG
[36]	x	x	Minimize emissions and environmental costs by satisfying technical restrictions
[37]	x	x	Minimize costs considering environmental aspects
[38]		x	Minimize the cost of network investments
[39]		x	Maximize the admissible capacity of the DG connected to the distribution network

5. HYBRID METHODS FOR THE LOCATION AND SIZING OF DG

Hybrid methods combine different optimization techniques with the intention of making the most of their different strengths and enabling a robust search in a large solution space. Among the main hybrid techniques are the combination of population

algorithms with simple heuristic techniques or with local searches.
Reference [40] presents a method that guides electrical distribution companies in the selection and location of DG in a meshed electrical system. This approach takes into account the system's limits, and maximizes the chargeability margin and the benefits for the distribution company. The proposed functions are converted into a single multi-purpose function with the use of diffuse logic. The model is solved using genetic algorithms. The genetic algorithm that is considered uses a fuzzy controller to adjust both the crossing and mutation relationships in a dynamic way, as to maintain the diversity of the population.

Reference [41] offers a new planning strategy for distribution system expansion, incorporating DG with the ability to generate reactive power. The types of generation that are considered are the following: wind-power, solar, and biomass. This Reference also analyzes factors such as the load that is demanded, wind velocity, and solar radiation using probability systems. The planning problem that is proposed is formulated through mixed integer non-linear programming (MINLP). The model is solved with the use of Particle Swarm Optimization (PSO) and ordinal optimization.

Reference [42] uses an approach that balances and compensates between loss minimization and the maximization of DG capacity. This approach has three stages. In the first stage, some approaches to the sampling process for a small group of potential combination alternatives are proposed. In the second stage, the value of the target function for each of the potential combination alternatives is evaluated with the use of a linear programming model that is computationally efficient. Afterwards, in the third stage, the best combination alternatives that were evaluated in the second stage are simulated using a non-linear power flow to uncover the best solutions for the location and sizing of the DG.

Reference [43] studies a hybrid method consisting of a genetic algorithm in conjunction with an optimal power flow, with the purpose of observing the acceptance capacity of the distributed generation in an existing distribution network. In [44] the authors proposed a new genetic algorithm combined with a Particle Swarm Optimization algorithm for the location and sizing of DG. The aim of this method is to minimize losses in the network to accomplish a better voltage regulation. Reference [45] offers a discreet hybrid particle swarm method in conjunction with an optimal power flow. The proposed algorithm brings about a better solution than the solutions achieved with genetic algorithms, for the same number of iterations.

Reference [46] presents a multiple-object planning model for distribution networks that optimizes the benefits for the distribution network operators as well as the benefits for the owners of the DG. It also takes into account the load uncertainty, the price of electricity, and wind power generation using the point estimation method. An immune algorithm paired with a genetic algorithm is used to solve the given optimization problem. Better results were achieved in comparison with the results yielded by heuristic methods. Table 4 summarizes the aspects that are considered in the location and sizing of DG by the meta-heuristic methods covered in this section. In this case, L corresponds to Location and S to Sizing.

Table 4. Aspects that are considered in the location and sizing of DG (hybrid methods).

Ref	***Variable***		***Objectives***
	L	**S**	
[40]	x	x	Maximize the chargeability margin and the benefits for distribution companies.
[41]	x		Minimize the investment costs and the operation in the planning process for the expansion of distribution systems with DG.
[42]	x	x	Minimize losses
[43]	x		Maximize the location of DG in an existing network
[44]	x	x	Minimize losses
[45]	x		Minimize losses
[46]	x		Maximize the benefits of the distribution network operator and the owners of the DG.

6. MATHEMATICAL PROGRAMMING METHODS FOR THE LOCATION AND SIZING OF DG

Mathematical programming has also been used to determine the best location and/or size of DG in distribution networks. In this area, Mixed-Integer Linear Programming (MILP), Non-Linear Programming, and Dynamic Programming can be highlighted. Given the nature of distribution networks, methods based on mathematical

programming for the optimal location of the DG regularly use simplifications of the power flow and/or power balance equations.
Reference [47] presents a multiple-objective approach for the optimal location of DG using dynamic programming. Loads that vary in time are analyzed, and the cost/benefit relationship for the DG is taken into account. [48] uses a probabilistic approach for wind-power generation in distribution systems. This model combines all the possible operating conditions of wind power DG and the charge levels with their probabilities. In this case, Mixed-Integer Non-Linear Programming (MINLP) is used as a solution for the model. The constraints that are considered are as follows: voltage limits, feeder capacity, discreet sizing of the DG units, an investment limit for every bus, and the limit for the penetration on the DG.

Reference [49] uses MINLP for the optimal location of the DG with a method that generates a probabilistic model relating generation and load. Its solution combines all the possible operation probabilities and the probabilities of renewable DG units, and uses deterministic planning for its analysis, considering voltage limits, feeder capacity, and a discreet sizing of the DG units. The technique is applied to a rural distribution system with different scenarios and all the possible combination of the renewable DG units.

Reference [50] presents a multiple-period AC optimal flow, using coordinated voltage control schemes and schemes for the modification of the power-factor of the DG, considering demand scenarios and variable generation. The aim is to locate different renewable DG resources in an optimal way.

Reference [51] uses MINLP for the optimal location of the DG. It starts by identifying the most appropriate area to install DG considering nodal prices, using a loss sensibility index as the economic and operational criteria. Additionally, it takes into account demand variation and market criteria.

Item [52] presents a Mixed Integer Lineal Programming model to locate the DG optimally in distribution networks in a bi-level programming scheme. In this case, simplifications of the power flow and loss equations for the distribution networks are used. Table 5 summarizes the aspects that are considered in the location and sizing of DG by the meta-heuristic methods covered in this section. In this case, L corresponds to Location and S to Sizing.

Table 5. Aspects that are considered in the location and sizing of DG (mathematical programming methods).

Ref	***Variable***		***Objectives***
	L	**S**	
[47]	x		Optimize the cost-benefit relationship of the correct location of the DG.
[48]	x		Minimize annual power losses.
[49]	x		Minimize losses using different types of renewable energy.
[50]	x		Maximize the location of different renewable DG resources.
[51]	x	X	Minimize power losses
[52]	x		Maximize the benefits for the DG network operator and owner.

7. CONCLUSIONS

This paper presents a literature review of the main methods used in the location and sizing of DG. In this review, it was observed that although some analytic methods have been used in the location and sizing of DG in distribution networks, these are limited, due to the fact that the simplifications that they use do not adjust to real cases (evenly distributed load, unitary power factor, etc.). On the other hand, the methods based on classical mathematical programming use simplifications of the load flow and power balance equations to maintain the convexity of the problem. The main advantage of these methods lies in their guarantee to obtain an optimal solution; their main disadvantage is their limitation when it comes to the simplified modeling of load flows and power balance. Finally, heuristic and meta-heuristic methods allow the use of non-linear load flow and power balance equations, but they do no guarantee the arrival at an optimal solution. Within the bibliographical revision, it was discovered that most of the methods used for the location and sizing of the DG employ meta-heuristic optimization, among which evolutionary algorithms can be highlighted.

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