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Planning Models for Distribution Grid: A Brief Review

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Abstract

The classic distribution grid planning problem was focused on determining a planning and expansion models of the electrical grid to guarantee mainly the energy supply for current and future loads and the technical and operational criteria of the grid, requiring for this, to make an orderly sequence of investments along the planning horizon. Nevertheless, the ongoing integration of distributed generation and energy storage devices has been leading to consider some changes on those models focus to deal with the complexity those integrations bring with them. In this context, this paper presents a brief review of distribution planning and expansion models with the perspective of identifying approaches, objective functions used, uncertainties analyzed, the computational and evolutionary techniques used, the dimension of the grid under analyses, among other aspects considered to solve the planning and expansion problem. This document will provide a background to find out the further works in this field.

Author Keywords. Storage, Power Distribution, Renewable Energy Source, Paper Review

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1. Introduction

The ongoing growth of energy demand, the electrification of new areas, and the climate changes are aspects that have been leading to companies responsible for providing the energy service to make investment to reinforce the distribution grid capability, to integrate new elements to the distribution grid and to operate isolated (Dufo-López, Cristóbal-Monreal, and Yusta 2016; Gao et al. 2014) in order to guarantee the energy supply. But, the investment decision represent a complex problem for planners because some aspects related to investment costs, grid reliability, technical losses, quality of service, maintenance, and operational cost (Ganguly, Sahoo, and Das 2013; Hongwei et al. 1996), among others, need to be considered along the planning horizon to find an appropriate sequence of investments to expand the distribution grid. Until some years, distribution grids were planned to predict changes in load centers, to reinforcement of grid elements (transformers, feeders, branches) and to ensure economic and reliable energy supply. Currently, the distribution planning and expansion problem has been enlarged by other aspects such as: uncertainties related to the integration of power generation from renewable sources (RES); the energy storage, the smart grids and other smart application at customer side (Sedghi, Ahmadian, and Aliakbar-Golkar 2016); and uncertainties associated to choices transformers and substation locations, demand evolution and location (Carvalho et al. 1998).

In this context, the distribution grid planning problem must find an appropriate way to make investments ensuring the energy supply (Yang and Nehorai 2014) along the planning horizon, allowing the integration of new energy generation from RES and accumulating the surplus energy in specific storage devices for use it later (Carpinelli et al. 2013; Nick, Cherkaoui, and Paolone 2014). By this reason, when the planning and expansion of distribution grids are made the planners must deal with the interdependent between the results and the randomness and uncertainties scenarios imposed by storage devices and renewable sources (Chung et al. 2003). Nevertheless, to find an appropriate planning along the horizon does not end the problem because a sequence to make investments to reach the expected grid and to operate that grid is itself a new problem that adds an important complexity to the main problem (Carvalho and Ferreira 2010; Yang and Nehorai 2014).

Usually, different models and computational and evolutionary techniques are used to deal with the complexity and to find a planning for the grid. The variables involved in the problem and size of distribution grid justify strongly the mathematical and/or meta-heuristic approaches required to solve the problem (Lee and El-Sharkawi 2008). The algorithms find a solution inside a set of possible combinations analyzed, thus providing an optimal solution under the conditions and restrictions formulated for each problem. According to the problem, algorithms based on meta-heuristic and mathematical modeling can be used (Careri et al. 2011; Gomez et al. 2004; Lavorato et al. 2010). In the other hand, regarding the objective to be achieved, it may be approached as mono/single-objective, multi-objective and multicriteria. About the stage, it can be approached as mono-stage or multi-stage (Miranda, Ranito, and Proença 1994). Other techniques, such as the decomposition, can be used to solve the problem for the large-scale system due to the complexity and computational restrictions. The decomposition consists in separating the problem in sub-problems and one master problem providing the solution at each level. It allows to minimize the computational effort and to accelerate the solution with dual dynamic programming (Carvalho et al. 1998; Nara et al. 1991).

The available alternatives to solve the distribution grid planning and expansion problem evidences the efforts by monitoring the evolution of this problem. Nevertheless, the ongoing integration of new generation from RES and energy storage devices to the grid, enlarge the problem because of the uncertainties that must be considered in the planning models. Although, in some cases have been also evidenced that the complexity was reduced considering forecasting models for some uncertainties.

2. Planning and Expansion Models of Distribution Grid

Distribution grid has been evolving at a rapid pace because the classical grid with top-down flows and uncertainties associated with load centers, evolved to a grid with bidirectional flows and uncertainties associated with the supply of energy generation and energy storage. As a consequence, the models, tools and techniques used to solve the planning problem have been improved in order to eliminate the shortcomings identified and to consider aspects such as: reliability, operational planning, optimal power flow, power generation expansion planning, reactive power planning, grid reconfiguration and approaches focused on probability or risk (Lee and El-Sharkawi 2008; Miranda and Proença 1998; Ganguly, Sahoo, and Das 2013).

The researchers around the world have contributed to propose several solutions for Generation, Transmission and Distribution grid planning problem using different approaches and different computational tools (Carvalho et al. 1998; Gönen and Ramirez-Rosado 1986; Khator and Leung 1997). These researchers proposed to solve the problem using mixed-integer linear programming, linear programming, geographical reference, genetic algorithms, evolutionary algorithms and bender decomposition. Related to the problem to solve has been considered some aspects such as: (i) find an optimal location and sizing of transformer, feeders, new generation from RES, and storage devices for minimizing costs; (ii) find an optimal sizing of new generation from RES and energy devices system for supply energy to the demand; (iii) improving voltage profiles and storage of surplus energy; (iv) find an optimal energy storage planning for isolated grid and microgrids; and (iv) find an optimal energy system (distributed, concentrated or semi-distributed), among others. On the other hand, one of the most important aspects considered by researchers to reduce the complexity of the problem refers to the uncertainties. Some of them considered forecasting models for the energy generation and load evolution for simplifying their analysis or to focus better on their objectives. Table 1 shows a brief review of the studied literature about distribution planning and expansion models with the objective to identify the approaches, objective functions used, uncertainties analyzed, the computational and evolutionary techniques used, the dimension of the grid under analyses, among other aspects considered to solve the planning and expansion problem. Two types of problems: (i) operational planning of distribution grid, and (ii) planning and expansion of distribution grid.

2.1. Operational Planning of Distribution Grid

The operational planning problem aims to study, analyze and propose solutions to improve the technical conditions of the grid. In this sense, Diaz-Dorado, Cidras, and Miguez (2002) considered a planning of urban distribution grid to obtain an optimal radial operation minimizing the total cost for loop, branches, and substations. To solve this, a genetic algorithm was proposed considering that an urban grid was defined with a graph containing all possible routes and known positions of the substations and switching stations. According to Wen et al. (2015) the problems of operational cost and voltage profile were studied considering the integration of energy storage and wind generation. The discretizing of wind power distribution based-on five-point estimation method was used. To solve this, a hybrid multi-objective particle swarm optimization and NSGA-II algorithms approach were used to establish the optimal siting for storage units considering the uncertainties in wind power production, to minimize the power system cost and to improve the voltage profiles.

Nick, Cherkaoui, and Paolone (2014) studied the optimal allocation of distributed energy storage for supporting the operation and active control in distribution. To solve this, a convex formulation was used to define a second-order mixed integer. The multi-objective optimization considered the investment, and maintenance cost and the operation cost. The operation function was used considering some virtual cost: grid voltage deviations, congestions of grid elements, technical losses, cost of supplying energy to loads, and stochasticity of renewable production and loads. According to Han et al. (2015) an optimized model of hybrid battery energy storage system was proposed to obtain the most economical types of batteries (lead-acid battery, lithium-ion battery and vanadium redox-flow battery), and capacity of energy storage. The selection and configuration of energy system is related to economic aspects and shifting on the grid. To solve this, a genetic algorithm based on games theory model was applied in order to obtain a design of battery energy storage station with an optimal configuration of batteries for revenues maximization.

Area	Type of Optimization Approaches	Objective	Test grid type	About Uncertainties	References
Planning and Expansion	A hybrid Tabu search / Particle Swarm Optimization Algorithm	Minimize the storage investment cost, O&M cost, reliability cost and number of technical constraints violations.	Test - 21 nodes / Grid of 13,8KV with 6,2MW peak load	Point estimate method is employed for probabilistic optimal power flow	Sedghi, Ahmadian, and Aliakbar-Golkar (2016)
	Particle Swarm Optimization / Shuffled Frog Leaping algorithm	Minimize of investment and operation costs and maximization of reliability index	Test - Distribution Grid of 13,8KV with 16 load points, 24 branches and 2 distribution substations	The loads are known	Gitizadeh, Vahed, and Aghaei (2013)
	Probabilistic Mixed-Integer programming / Genetic algorithm	Minimize the investment cost of distributed generation and energy storage, and the fuel cost for diesel generators	A small autonomous power system with 150 kW peak load	The loads are modelled as probabilistic distributions	Hong et al. (2015)
	Mixed Integer Linear Programming	Minimize the investment cost, operational cost and energy losses cost in the circuit branches	Real grid of 75 Bus (38 Bus in Primary and 37 in Secondary Grid)	Previous load flow	Paiva et al. (2005)
	Separable Linear Programming / Multi-Stage Dynamic Planning	Minimize the investment cost, operational cost, maintenance cost and energy losses	Rural distribution grid of 90 nodes	Previous load flow	Farrag, El-Metwally, and El-Bages (1999)
	Quadratic Mixed Integer Programming	The number, size and location of substations loading and routing of the feeders in an area for a given demand level at the load locations	Numerical Test - 9 nodes	The load is known	Ponnavaikko, Rao, and Venkata (1987)
	A Nonlinear Continuous Model	Minimize the future cost considering an optimal parameters design and reliability	Assumption: substation coverage has an approximation with a polygon and the branches are perpendicular to radial feeders	Multipliers was used to define the system element: costs energy, load characteristics, and consumer interruptions, system parameters, transformer characteristics.	Fletcher and Strunz (2007a)
				The protection scheme includes one automatic protection device installed midway on the main feeder. The main feeder has automatic fault isolation	Fletcher and Strunz (2007b)
	Genetic Algorithms	Analyzed the planning problem under probabilistic choice and risk analysis paradigm approaches	Test - 54 nodes distribution grid of 15KV	Probabilistic Choice vs. Risk Analysis / Three load sceneries were defined by load forecast	(Miranda and Proença 1998) (Miranda and Proença 1998)

Particle Swarm Optimization	Minimization of total cost of installation and energy loss and minimization of total non-delivered energy	Mono-objective: Test-54 node Indian distribution grid / Test-182 node Spanish grid Multi-objective: Test-100 node distribution grid / Test-182 node Spanish grid	The load is known	Ganguly, Sahoo, and Das (2011)
Heuristic Algorithm / Multi-source locating algorithm	Minimize the investment cost, operational cost of future substation and the cost of energy losses in a planning model	Real grid of 10KV with a distribution grid that cover an area of 500km2, the urban area was around 162 km2	Spatial electric load forecasting.	Hongwei et al. (1996)
Mixed Integer Nonlinear Programming / A constructive Heuristic Algorithm	Minimize the total investment cost subject to operation constraints	Test-23 node distribution grid of 34,5KV / Test-54 node distribution grid of 13,5KV / Test-136 node distribution grid of 13,8KV	The energy losses cost, loss factor and load are known	Lavorato et al. (2010)
MINLP / Ant Colony system	Minimize the investment cost and the operational cost	Test-23 node distribution grid of 34,5KV / Test-201 node distribution grid of 10KV	The maximum allowed voltage deviation, power factor and load are known	Gomez et al. (2004)
Mixed Integer Programming / Branch and Bounds	Substation sites and feeder routes for the most economical distribution voltage and substation capacities	Test - based on Northwest Mesa area of Albuquerque / 87 nodes and 324 branches	Load is specified using a piecewise linear curve / 168 branches with fixed load	Sun et al. (1982)
Genetic Algorithm	minimize the new facility installation costs and operation costs, and to obtain an acceptable level of reliability	Test-50 node distribution grid of 15KV	The load is known / Possible location for substation and lines are know	Miranda, Ranito, and Proenca (1994)
Mixed Integer Linear Programming / Branch exchange	Minimization of investment cost and operational cost (losses)	Test-59 node distribution grid of 6.6KV	The load is known	Nara et al. (1991)
Tabú search / Dijkstra Algorithm/ Ford–Fulkerson Algorithm /Branch exchange	Minimize installation costs of new facilities	Test - 7 feeders, 9 open switches, 198 street sections, 6 leading point candidates and 2 transformer candidates	The load is known	Nara et al. (1998)
Quadratic Mixed Integer Programming / Bender Decomposition	Minimize the combined costs of the construction of substations and feeders with that of losses occurring at fundamental and harmonic frequencies	Test-9 nodes	Type and location of load are known	Singh, Makram, and Adams (1998)

	Genetic Algorithms / Decompose the Problem	Find a best first stage investment that minimize the expected future and actual costs	Test-15nodes	Forecasts of the uncertain parameters for the first stage	Carvalho et al. (1998)
Operation Planning	Hybrid= MOPSO+NSGA-II	$\min f_1 = \sum_{i=1}^{5} \mathrm{Prob}_i \cdot \mathrm{Cost}_i \quad \min f_2 = \sum_{k=1}^{n} \left(\frac{V_k - V_k^{\mathrm{spec}}}{\Delta V_k^{\max}} \right)^2$	IEEE - 30 Bus	Monte Carlo method, a five-point estimation method/Optimal load flow	Wen et al. (2015)
	Convex formulation of ac optimal power / Mixed Integer Second-Order Cone Programming	Minimize investment and maintenance costs of storage system and operation cost of grid	IEEE - 34 Bus	Data Clustering K-Mean Method (loads, PV and wind)	Nick, Cherkaoui, and Paolone (2014)
	Genetic Algorithm / Games Theory Model / The Nash Equilibrium	Maximize the revenues of configuration batteries		Technical characteristics of batteries are known / typical daily load curve	Han et al. (2015)
	Mixed-integer non-linear constrained programming / Genetics Algorithm / Inner Algorithm	Minimize the total cost of the sum: losses, reactive power imported from HV grid, reactive power provided by DG units, energy for price arbitrage, installation of batteries, installation of capacitors and network upgrading	Test - 17 nodes / Grid of 12,5KV with connection to HV through 138/12.5 kV, 18 MVA transformer	The load is known, and DG power productions are assumed to be characterized by assigned typical daily variations and growing rates in the planning time horizon	Carpinelli et al. (2013)
	Dual Programming based-on Alternating Direction Method of Multipliers Algorithm	Minimize the total cost (investment, operation and maintenance cost)	Test - A micro-grid is usually on the scale of 5–10 MW	The loads are known / The solar and wing generation were calculated using the NSRDB from National Renewable Energy Laboratory (USA)	Yang and Nehorai (2014)
	Improved Bat Algorithm	Minimize the fixed operation and maintenance cost of distributed generators and the total cost of batteries energy storage	Test - 14 nodes / Micro-grid of 400V with connection to MV through 20/0,4KV transformer	The load demand, energy prices, PV and WT power output are known	Bahmani-Firouzi and Azizipanah-Abarghooee (2014)
	Genetic Algorithms /Heuristic Algorithms	Minimize the total cost for loop, branches, and substations to obtain an optimal radial operation	Real grid of Vigo city with 242 substations, 6 switching stations and 195MW installed, that represent 1852 nodes and 2996 branches	The load and position of substation/switching are known	Diaz-Dorado, Cidras, and Miguez (2002)

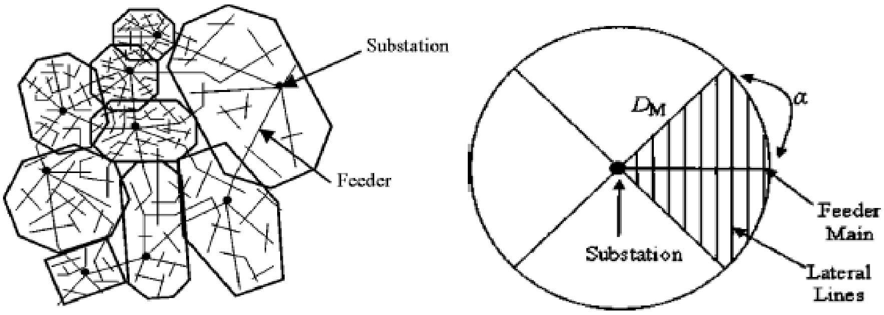
Table 1: Research list of approaches used for planning and expansion distribution grids

Carpinelli et al. (2013) analyzed the optimal integration of energy storage devices in a medium voltage smart grid connected to a high voltage grid through a transformer for sizing and siting batteries and capacitors to provide internal services (technical loss reduction) and external (supply reactive power). To accomplish this, an optimization problem based-on mixed-integer non-linear constrained programming, genetics algorithm and inner algorithm (based-on sequential quadratic programming) was proposed for minimizing the total operational cost. According to Bahmani-Firouzi and Azizipanah-Abarghooee (2014), it is important to analyze the optimal sizing of energy storage to operate on microgrids, considering the large integration of RES in order to minimize the operation and maintenance cost of distributed generators (DG) and the total cost of batteries energy storage (BES). To solve this, a new evolutionary technique was proposed for development strategies and minimum cost dispatches. This evolutionary technique focuses on improving the bath algorithm including a meta-heuristic approach that allows a new self-adaptive learning that enhancing the searchability of the algorithm. The constraints considered to solve the problem refers to the load demand balance, the operation point of each dispatchable DGs, the discharging and charging of BES and the sum of reserved electrical power generation capacity obtained when the BES is turned on. Tests were carried out for three different cases: (i) the microgrid without BES, (ii) including BES without initial charge and (iii) including BES with the initial charge equal to the size of BES. The results showed that BES could decrease the cost of the microgrid because BES can store the surplus energy of RES and dispatch it later appropriately. On the other hand, the improve bath algorithm proposed was compared against to the original bath algorithm.

Yang and Nehorai (2014) studied the optimal planning to minimize the total cost (investment, operation, and maintenance) of different energy storages and RES in a hybrid microgrid. To achieve this, a dual programming based on alternating direction method of multipliers algorithm was employed to mitigate the time complexity problem and make it scalable. Tests were carried out considering three (3) operation cases of the hybrid-grid such as: ration maximum diesel generation capacities; different diesel generation costs; and compared the different planning results in different geographic regions. The results allowed to take decisions on energy storage and generation capacity planning with RES because of the diesel generation cost affects the trade-off between renewable energy and traditional fossil energy, while the diesel generation capacity affects the planning for renewable generation and energy storages. Also, the geographic location had a significant impact on different renewable energy sources and the loads.

2.2. *Planning and Expansion of Distribution Grid*

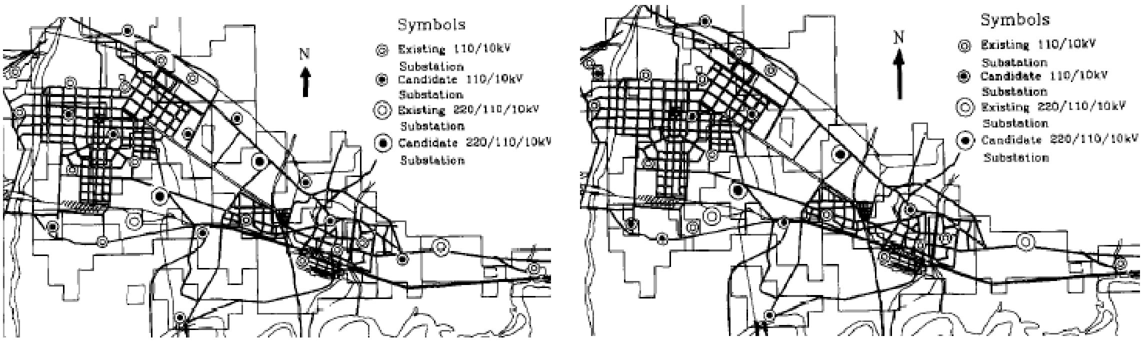
The planning and expansion problems are focused in studying, analyzing and proposing solutions to upgrade the grid through the integration of new elements or load while the technical conditions of the grid are analyzed. In this sense, Fletcher and Strunz (2007a) considered the optimal horizon distribution planning and system model based on the minimization of the future cost considering design parameters and reliability. These parameters were: (i) substation and distribution transformer capacities; (ii) number, size, and lengths of distribution feeders, and (iii)primary and secondary conductors. A nonlinear continuous model was used to find an optimal total installation and operational cost per consumer. The topology design corresponds with an ideal assumption, where each coverage substation has a reasonable approximation with a polygon or circle, and the branches are perpendicular to the radial feeders. To analyze the reliability, it was assumed that the main feeder includes an automatic fault isolator and a protection device on midway as shown in Figure 1.



a) Substation **b) Radial Feeder**

Figure 1: Assumption of ideal topology for planning the Primary Distribution System (Fletcher and Strunz 2007a)

Hongwei et al. (1996) studied the planning of substation location and size aiming to minimize the investment cost, operational cost of future substation and the cost of energy losses in a planning model. For this, it was considered a distribution power system as a grid of small squares or sectors with the load in a central point where the magnitude of load is given by the product of load density and the area of the sector, as shown in Figure 2. To solve this, a heuristic combination optimization algorithm and a multi-source locating algorithm were used.



a) **b)**

Figure 2: Plot of a manual (a) and automatic (b) planning (Hongwei et al. 1996)

Lavorato et al. (2010) considered the planning and expansion of distribution grid problem to minimize the total investment cost (fixed and variable costs). To achieve this, a constructive heuristic algorithm was used to solve a problem modeled as a mixed integer nonlinear programming where the discrete variables represented the construction or reinforcement (or not) of circuits and substation. According to Paiva et al. (2005), the formulation of planning distribution grid problem has to include the primary and secondary radial distribution grid, to minimize the cost function, which consists of investment cost, operational cost, and energy losses cost in the circuit branches. For this, a two-step approach was proposed. In the first step, linear programming was used to determine some initial solution; and in the second step, a search was used to find an appropriated solution. Also, other researchers have considered mixer-integer linear programming under a two-step approach (El-kady 1984; Gönen and Ramirez-Rosado 1987) for studying and analyzing the distribution expansion problem.

Farrag, El-Metwally, and El-Bages (1999) studied the expansion planning of radial distribution grid using a separable linear programming technique in order to establish an optimal sitting for substation and sizing transformer, optimum expansion for existing substation, optimal load transfer and optimal routes and feeders sizing, considering dynamic programming. The cost function was determined considering that: (i) the path was represented by two paths with different power flow direction; (ii) the substation was represented by one path with direction identified; (iii) the new substation site was represented by a specified number of path of the same direction depending of number transformer size. For each node two set (set of input or feeding paths, and set of outgoing paths) were determined. This technique was used because mixer-integer linear programming was considered impractical for real distribution grid. On the other hand, for Sun et al. (1982) the objective of radial distribution planning took into account the system designed and the effects of demand expansion along the planning horizon for determining the substation location and feeder routes, to select the most economical distribution voltage and substation capacities, to determinate the effect that different sub-transmission lines routings and voltage levels would have on the distribution substation and primary feeder routes and know the impact on system design due to changes in load densities and load growth rates. To accomplish this, mixed-integer programming and Branch and Bonds technique was used in order to indicate a lower bound of cost for all branches. If the cost of any branch was greater than the lower bound, it was not considered.

Miranda, Ranito, and Proença (1994) analyzed the distribution grid planning problem using genetic algorithms that keep the canonical orientations aims to find an optimal sizing, timing and location of distribution substation and feeder expansion. To achieve this, the objective proposed was to minimize the new facility installation costs and operational costs for obtaining an acceptable level of reliability taking into account the operation of the networks under radial configuration, power demand specifications, and possible location for substation and lines, among others. Nevertheless, Nara et al. (1991) studied the expansion planning problem of distribution grid considering the minimization of investment cost and operational cost (losses). To solve this, mixed-integer linear programming modeling and branch exchange decomposition were approached. The branch exchange decomposition proposed to decompose a planning problem with n-years in n one-year planning problems, where one-year was coordinated under consideration of forwarding/backward path, which consists of adding one branch to initial grid configuration and removing another branch to regenerate some solutions. After that, Nara et al. (1998) minimized the installation costs of new facilities to find a solution of the expansion planning problem in urban areas considering the load-balancing, current capacity, voltage drop and geographical installation restrictions.

Carvalho et al. (1998) proposed an optimal distribution network expansion planning under uncertainty with multi-stage considerations. The objective was to find a best first stage investment that minimizes the expected future and actual costs. The researcher considered that the first stage should have a good forecast of the uncertain parameters because the information becomes available for the next scenario; each scenario corresponds to a set of possible node locations. A genetic algorithm was proposed to decompose the problem into K deterministic problems and evaluate each of the decisions with the correspondent scenario cost function. The policy for each planning stage is defined as the set of nodes to relate to an existing network, where the first stage deals with a common policy.

Ponnavaikko, Rao, and Venkata (1987) proposed an approach for the optimal sizing and siting substation and network routing based-on quadratic mixed integer programming. In a first stage, the quadratic mixed integer programming was solved treating the variables as continuous variables. In a second stage, the values of integer variables were converted into integer values. In the other hand, Singh, Makram, and Adams (1998) proposed a new model for optimally sizing and locating distribution substations and feeders in a time-dynamic power distribution system aiming to minimize the combined costs of the construction of substations and feeders considering that losses occurring at fundamental and harmonic frequencies. To solve this, the benders decomposition to divide the mixed-integer model to a pure 0–1 relaxed master problem (construction of new facilities substations/feeders) and a quadratic sub-problem (optimize power flow for minimizing the operational costs) were used.

Gomez et al. (2004) analyzed the planning distribution problem aims to minimize the fixed costs correspondent to the investment and the variable costs correspondent to the operation of the system using an ant colony algorithm and modeling the problem based-on mixed integer nonlinear programming. Initially, a random level of pheromone was deposited in each branch of the grid and some ants accomplished independent explorations through the different branches guided by a heuristic function and probabilistic transition rule. According to Miranda and Proença (1998), the planning problem need to be compared between probabilistic choice and risk analysis paradigm in order to evaluate the consequences of adopting these points of view. In the probabilistic choice paradigm, the solution chosen did not know the future scenery, therefore, it could evaluate the discrepancies. In the risk analyzes paradigm, the solution chosen had the ability to know the consequences of adopting any solution before future scenarios would happen. For this, genetic algorithms were used to establish the consequences for adopting each paradigm. The results obtained showed that in some cases the solution proposed was the same but, in other cases the risk analyses would detect some interesting solution.

Ganguly, Sahoo, and Das (2011) studied the static expansion planning of distribution grid under mono and multi-objective approaches using particle swarm optimization (PSO). The objectives considered were: (a) minimization of total cost of installation and energy losses and (b) minimization of total non-delivered energy. Different PSO variant (constriction factor PSO, PSO with inertia weight and Comprehensive learning PSO) were verified with a statistical test.

For Sedghi, Ahmadian, and Aliakbar-Golkar (2016), the optimal batteries planning required (i) minimization of the cost objective function considering the location, capacity, and power rating, and (ii) maximization of the schedule of batteries. To achieve this, the point estimate method for probabilistic optimal power flow, a hybrid tabu search, and particle swarm optimization were used. The tabu search was used to solve de optimal power flow. The proposal contained two main loops aims to evaluate the optimal planning of storage problem. According to Gitizadeh, Vahed, and Aghaei (2013) the distribution planning problem in presence of DG requires finding the grid topology and optimal placement of these sources (to obtain a configuration of feeders, size of branch conductor and operation point of DGs) minimizing the investment and operational costs and maximizing the reliability index, along a planning horizon of 4-years. To accomplish this, a hybrid particle swarm optimization (PSO) and shuffled frog leaping (SFL) algorithm were employed. The results showed that for multi-objective considerations, it was not possible to minimize the cost without deteriorating the performance of reliability. Hong et al. (2015) considered the power generation planning with energy storage in an isolated grid in order to minimize the investment cost of DG, energy storage, and the fuel cost for diesel generators. To solve this, a genetic algorithm based-on mixed-integer non-linear programming was employed to determine the optimal capacities of wind-turbine-generators, photovoltaic generators, diesel generators and energy storage.

3. Analysis of Planning Model of Distribution Grid Approaches

The planning and expansion distribution grid represent a complex optimization problem for planners because some aspects such as: type of variables decisions, uncertainties enrolled in the problem, objective function representation, choice of conductor size and feeder route, considerations of geographical and social issues to locate de substations, among others, need to be considered in order to propose a way to obtain a model for finding an appropriated planning and expansion of distribution grids. The researches presented in this document have incorporated some aspects aforementioned in order to propose a way to solve the problem. Some of these researches simplified the models using assumption, such as, forecasting or statistical data. Some salient features of different planning approaches are exposed below:

- The most frequently objective function is focused on minimizing the investment and operational cost. Nevertheless, some objective function considered the maximization of reliability index or minimization of non-delivered energy.
- Some approaches were linearized, or some assumptions were considered to deal with a less complex problem.
- The evolutionary algorithms were powerfully used as solution strategies for medium and large systems (based-on test system information.

On the other hand, the identified trend is the integration of distributed generation from renewable energy sources and energy storage devices. A glimpse of these researches is exposed below:

- The reported works were aimed at determination of optimal number, site, and size of energy storage devices and distributed generation.
- Different solution strategies were used: mixed-integer programming, particle swarm optimization, problem decomposition and evolutionary algorithm.
- In some models, the uncertainty in load demand and generation is modeled by different probabilistic scenarios.

3.1. Some Future Research Directions

More investigations are needed considering the following aspects:

- Long-term multi-stage and multicriteria planning approach for radial and open meshed distribution grid topologies.
- A generation types mix and energy storage devices for planning both primary and secondary distribution grids.
- A consideration of the continuity of energy service index as a representative objective for planning distributions grid. This aspect is relevant in several countries where the energy not supplied index reach a lot of hours.
- An approach computationally efficient to promote its adoption by the industry.

4. Conclusions

There are in the literature a several proposals to solve the planning and expansion distribution grid problem. It demonstrates the efforts by monitoring the evolution of it problem. Nevertheless, the integration of generation from RES and energy storage to the grid, enlarge the problem by the uncertainties, which add complexity to the models. In some cases, this complexity could be reduced with forecasting of the uncertain parameters, forecast variation of the production of RES or the operation state of energy storage (loading/unloading), among others. Despite efforts, It is necessary to present new research proposals for developing a model for energy storage planning in distribution grid with RES integrated, able to deal with uncertainties scenarios, multiple-objectives (under multicriteria characteristics), and computationally efficient in a way compatible with its adoption by the industry.

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