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Review on Power Distribution Planning in the Modern Power Systems: Methods

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Abstract: *In recent years, a large amount of study work has been dedicated to determining how contemporary power distribution systems might be designed to be as efficient as possible. The purpose of power distribution planning, often known as PDP, is to build the distribution system in such a way that it can promptly satisfy the demand increase in the most reliable, cost-effective, and secure manner that is feasible. During the planning process, it is necessary to take into account not only the influence of active demand and distributed generation but also the increasing benefits of their respective control as a result of the progressive transition of the distribution grid from a passive to an active state. In recent times, a number of different solutions to the contemporary PDP issue have been put up for consideration. In this work, an overview of the most recent and cutting-edge solutions that have been applied to the current PDP issue is presented.*

Keywords: PDP Problems, Economical, Reliable, Safe, Grid

I. INTRODUCTION

In the context of power distribution planning (PDP), the major objective of the designer of the power distribution system is to build the distribution system in such a way that it can satisfy the demand increase in a timely manner in the most cost-effective, reliable, and secure manner possible. This is not a simple task owing to the extremely wide extension of the power distribution system, as well as the fact that this system is responsible for the majority of the electrical energy losses and the majority of the interruptions due to faults. Additionally, this system is responsible for the majority of the outages. In general, the classic PDP involves identifying the best cost-effective solution (single objective function) that combines the ideal placement and size (capacity) of future substations and/or feeders to satisfy the anticipated level of demand. The classic power distribution plan (PDP) has as its goal the reduction of an economic cost function, which includes the investment cost to construct, fortify, or replace substations and/or feeders as well as the cost of energy loss. This goal must be accomplished while adhering to a number of technical and operational limitations.

The significant penetration of distributed generation (DG) technologies in recent years, including storage, as well as the engagement of consumers in the form of active demand, which is promoted by national and regional laws globally, have further complicated the distribution planning function. This has been the case particularly in recent years. This is the fundamental idea of an active distribution network, also known as an ADN, which plans its operational aspects to include distributed generation, distributed storage, active demand, automation, communication, and improved metering. Instead of simply connecting distributed energy resources (DER) to the network (the so-called "fit and forget" approach), it is now generally accepted that it is possible to achieve optimal planning solutions while simultaneously saving a significant amount of money by utilizing the capacity and control capabilities of distributed energy resources (DER) at the distribution level. For instance, the optimum placement of DG inside existing power distribution networks has already drawn the attention of significant research efforts [1] over the course of the last twenty years, with the first study published in 1994. This topic has been the focus of significant research efforts [1] over the course of the previous twenty years. In the articles [2–4] that were written and published in 1997, 2000, and 2002, respectively, a comprehensive analysis of the PDP's body of work is presented. Regarding the modern PDP of active distribution networks, it will be shown later in Table 2 that the consideration of automatic switching actions appears in 2005; the consideration of DER integration and control appears in 2007; and the consideration of multiple controls (active and reactive power control of DG units, on-line network reconfiguration, demand side response, and generation curtailment) appears in 2008; these dates will be shown. This article offers a review of a selection of PDP works that were released after 2005 (the year the first contemporary PDP was published) [5–81]. It is important to note that in [1], 83 current papers on the appropriate placement of DG into existing power distribution systems were evaluated, however in this work, 77 current publications on contemporary PDP are covered, which are completely different from the publications that were reviewed in [1].

II. POWER DISTRIBUTION METHODS

2.1 Numerical Methods

2.1.1 Mixed-integer Linear Programming

The formulation of a multistage distribution expansion issue as a MILP problem allows for the problem to be solved by a branch-and-bound algorithm or other conventional commercial solvers [20,21,24,46]. The formulation and solution of an integrated planning approach for primary–secondary distribution networks utilizing MILP [6] are presented. The MILP algorithm is used to define and solve a spatial PDP [52].

2.1.2 Non Linear Programming

Continuous restricted NLP is performed in order to solve a generalized horizon planning model that looks at least twenty years into the future and has 10 decision factors (design variables) [16,18]. The Benders decomposition method [31] may be used to solve a PDP that is based on a mixed-integer NLP. It is possible to design a dynamic PDP by making use of two interrelated models, each of which may be solved by either MILP or NLP [34].

2.1.3 Dynamic Programming

DP solves a multistage PDP [19,40] and a multi-objective PDP [65].

2.1.4. Ordinal optimization (OO)

OO simultaneously optimizes PDP and electric vehicle charging stations planning [81].

2.1.5. Direct solution

The optimal feeder routing is solved by a direct approach that depends only on tracking radial paths and computing the cost of the paths [51,56].

2.2 Heuristic Methods

2.2.1 Genetic Algorithm(GA)

The GA approach is used in order to resolve the PDP issue [7,32,37,49,60,61,64,70]. GA is used in combination with quasi-Newton [9], optimum power flow (OPF) [47,57], and branch exchange [62] to solve the PDP. A multistage PDP that contains uncertainty may be solved using a balanced genetic algorithm (GA) in conjunction with data envelopment analysis [43]. In order to solve a PDP taking DG connection into consideration, graph theory and GA are integrated [35]. The use of GA is used to address two different problems: (1) the issue of the optimum MV substation, and (2) the problem of the optimal HV substations location and feeders routing [28]. Co-optimization of distributed generation (DG) and smart metering allocation may be achieved concurrently with network reinforcement by using an interior point approach incorporated discrete GA [77]. In order to solve the PDP of open-loop MV networks, a multi-objective genetic algorithm (GA) is used with geographic information systems (GIS). An NSGA, which stands for non-dominated sorting GA, is used for PDP. [13,73]. A multi-objective PDP may be solved by using a variation of the NSGA known as NSGA-II [12,38]. A multistage PDP may be solved using a genetic algorithm (GA) that has problem-specific fix, crossover, and mutation operators [23]. Finding the architecture of the distribution network that is most effective requires an evolutionary strategy that is based on recombination [8]. A MINLP issue is used to model the design of secondary distribution networks, and an evolutionary strategy is used to find a solution to this problem [5]. An application of a strong Pareto evolutionary algorithm, also known as SPEA, is used for PDP [13,27].

2.2.2 Tabu Search(TS)

In order to solve a fuzzy model for a multi-objective PDP issue, a TS technique is used. This method computes the non-dominated solutions that correspond to the simultaneous reduction of the fuzzy economic cost, the fuzzy predicted non-supplied energy, and the risk of overloading the feeders and/or substations [11]. The approach of [33] in conjunction with Voronoi diagrams and TS [30] is a good way to solve the LV PDP of a real scale distribution firm. The LV PDP may be solved by using TS in combination with a constructive heuristic algorithm (CHA), as stated in [33]. A PDP that takes into account DG and uncertainties may be addressed by TS with the help of an embedded probabilistic power flow model that is based on Monte Carlo simulation [79]. The dynamic PDP may be solved using multi-objective TS [74]. A PDP may be solved by using multi-objective reactive TS in conjunction with CHA and GA [54]. Both TS and simulated annealing (SA) were used in an effort to solve the PDP; nevertheless, the researchers came to the realization that TS is more effective than SA [36].

2.2.3 Particle Swarm Optimization (PSO)

A discrete PSO, also known as a DPSO, is responsible for the concurrent design of the MV and LV networks [48]. PDPs may be solved using a modified version of the DPSO that takes into account both DG and cross-connections [55,66]. A modified PSO with local search is used to solve a PDP that takes DG and storage into consideration [71]. A PDP that contains uncertainty may be solved by an evolving PSO that takes DG into consideration [68,69].

2.2.4 Evolutionary Algorithms(EA)

A multi-objective PDP that additionally co-optimizes electric car charging system planning may be optimized with the use of a decomposition-based multi-objective evolutionary algorithm [78]. This algorithm searches for the Pareto front, which consists of non-dominated solutions. The seeker optimization method is a population-based evolutionary system that concurrently optimizes the PDP and automated recloses allocation [80].

Ant Colony System (ACS)

A dynamic ACS algorithm solves a PDP that considers the installation of DG together with the reinforcement of feeders and substations [15].

Bacterial Foraging (BF)

A BF technique solves the optimal feeder routing problem [50].

Simulated Annealing (SA)

The PDP is solved by SA in combination with a steepest descent method [22] and in conjunction with MILP in [75].

Artificial Immune System (AIS)

An AIS optimization method computes a set of nearly optimal solutions, which are next evaluated by a Monte Carlo simulation that considers load uncertainty, and, finally, the solutions are compared via a multi-objective analysis [17]. An immune system memetic algorithm, i.e., the AIS of [17] is combined with a network local search to solve the PDP under load uncertainty [42].

2.2.9 Artificial Bee Colony (ABC)

ABC computes the network reinforcements and the commitment schedule for the installed generating units [67].

2.2.10 Practical Heuristic Algorithms(PHA)

A difficulty with the value-based dependability planning of a distribution system may be solved by using a heuristic technique [10]. An method that uses a constructive heuristic approach is used to solve the PDP [25,39,59,63]. The issue of feeder routing in distribution networks, including DG, may be solved using a technique called minimal spanning tree [76]. A PDP may be solved using a heuristic technique, which can then be used to boost the penetration of DG [53]. A heuristic algorithm has been developed in order to solve the PDP, and a statistical method has been developed in order to assist network planners in determining the optimal design strategy for certain kinds of LV networks [45]. Both of these developments have been made. The PDP may be solved by using a method known as branch-exchange in conjunction with the least spanning tree [41] and the DP [44,58]. The Power Distribution Problem (PDP) is broken up into two distinct issues: the substation problem and the feeder problem. The substation problem is handled using a pseudo-combinatorial algorithm. Next, the feeder problem is solved using two distinct methods in successive order: the node ordering and the node ordering directed branch exchange [14]. A secondary distribution network's geographic zone is segmented into a number of smaller zones, and the LV PDP is solved individually across all of these zones using a combination of heuristic algorithm and clustering approach [29]. In [72], there is a proposal for a heuristic technique for dynamic PDP that is based on back-propagation of the planning process beginning with the last year.

III. CONCLUSION

This paper presents a thorough overview of the state of the art optimization methods applied to the PDP problem in the last decade.

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