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OPTIMAL PLACEMENT AND SIZE OF DISTRIBUTED GENERATION IN DISTRIBUTION NETWORK: A REVIEW

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ABSTRACT:

Traditionally the electric power is supplied (Generated) by centralized power plants such as thermal, gas, hydroelectric and nuclear power plants and electric power is transmitted over long distances to substations. Distributed networks are generally Radial distribution type is preferred for simplicity of operation. Radial distribution systems (RDS'S) are supplied by only one substation, there no alternate backup supply. Radial distribution systems, a passive network, are used to deliver electricity to end users from substations. Because of the unidirectional flow of electricity in RDS and the high resistance to reactance R/X ratios, low voltage stability, large voltage drops, and large power losses are common. A problem like voltage drops also manifests itself under extreme stress situations. A suitable answer is to place distribution generation inside the distribution network; however distribution generation calls for right set up to optimize the appropriate placement and size of it. Various techniques are used for distribution generation allocation are categorized as 3groups, specifically classical, analytical and heuristic approaches. The classical technique is good enough for small distribution network, but it turns into complex for larger networks. The analytical method is simple to use, but it doesn't always provide the best answers. Meta-heuristic techniques like Genetic Algorithm and other realistic heuristic algorithms are fast and change is actually possible. All varieties of optimal issues cannot be solved with a single optimization strategy. The performance of optimal techniques slides from problem to problem. For a variety of real-world engineering challenges, testing alternative optimization strategies is always necessary. An overview on ideal placement and size of distribution generation set up has been pursued in this article. This paper describes and compares various solution methodologies related to solutions for distribution generation integration in distribution system.

KEYWORDS:

DISTRIBUTION GENERATION, OPTIMAL PLACEMENT OF DISTRIBUTION GENERATION, VOLTAGE PROFILE.

INTRODUCTION

The increasing population across the globe is giving a challenge to the energy department to compensate the energy demands. The US Department of Economic and Social Affairs [1] estimates that the population of the world will exceed 8 billion in 2022 and will reach 10.9 billion in 2100. In order to satisfy future demands, it is necessary to upgrade and improve current energy sources and energy systems. As a result, the daily increasing power demand means that conventional power sources are declining. As a result, distributed generation (also known as distributed generation) is a better solution. A distribution power generation unit is a small power generation unit that is directly connected to the distribution grid. A common definition of distributed generation [2, 3] is a power source directly connected to the distribution grid. According to a report released by the International Energy Agency, market analysis & forecasts for 2019-2024 [4], Global renewable energy generation capacity is projected to rise by 50% between 2019 and 2024. Among renewable energy generation, solar power is likely to show the highest growth rate of around 60%. Further estimate whether appropriate policies and sustainable infrastructure are adopted globally, renewable energy generation will play a major role by 2050, adequately meeting about 80% of global energy demand.

Presently, the demand for energy is growing worldwide, and centralized power generation cannot meet this demand. The complexity of distribution is growing daily, while population increase is making conventional planning methods ineffective from a distribution standpoint. Thus, distributed generation, where power is generated in load centers, has emerged as a viable alternative [5]. Renewable energy sources are available in distribution power generation like Photovoltaics (PV), Wind Turbines, Microturbines, Fuel Cells, and Battery Energy Storage Systems. The implementation and operation of distribution generation by utilities and consumers can minimize electricity demand.

II. OBJECTIVE FUNCTION

Population growth and economic development are increasingly dependent on electricity. Installation of distribution generating units in the distribution network is necessary for continuous supply. The power distribution generation unit must be placed in a suitable position in order to avoid interfering with the system's functioning and power quality. Several strategies for organizing distributed generations have been put out recently. This article describes a few of these techniques. A single objective function or a collection of objective functions can result in the best placement and size distribution. The following are the key objective functions for generating distributions with the best placement and size:

- Minimize energy costs
- Minimize power loss
- Improves the voltage profile
- Minimize the system average interruption duration index (SAIDI).
- Determine the design variable for Distribution Generation placement such as size and location.
- Maximize Distribution Generation capacity.

III. DEFINITION OF DISTRIBUTED GENERATION

Distribution generation is described by the International Energy Agency (IEA) as a power producing plant that feeds electricity into the grid at the local consumer or distribution level [6]. According to the IEEE, distribution generation is the output of installations that are sufficiently smaller than a centralized power plant to allow connectivity at virtually any point in the power system. Distribution generation is defined by the International Council for Large Power Systems as the production of smaller than 100 MW of electricity which is either centrally organized or centrally dispatched & typically connected to distribution networks. Also, Distributed generation, defined by the Electric Power Research Institute (EPRI), is small-scale generation up to 50 MW [7]. Micro turbines, reciprocating engines, combustion gas turbines, fuel cells, solar systems, wind turbines are a few of the power generating technologies available today. These distributed generating technologies each have unique characteristics and advantages. Because distribution generation is so common in the distribution network, it needs to be scaled correctly and optimally allocated to reduce power loss and improve voltage profile, power quality & reliability.

Distributed generation, including both dispatched & non-dispatched distribution generation, could become a major power source. "Dispatched" here refers to a power generation source from which the supply center can control power as needed. Examples include microturbines, diesel generators, fuel cells and battery energy storage systems (BESS), flywheel energy storage (FES), super capacitors, super magnetic energy storage (SMES), there is various energy storage technologies such as, Pumped Hydro Storage Stations (PHES) etc. Once the availability of an electric vehicle (EV) has been confirmed for a period of time, it can be said to have shipped. And “non-dispatched” refers to power generation fueled by natural resources. Photovoltaic, wind, hydro & geothermal energy are considered undetermined. Wind turbines & photovoltaics (PV) are considered non-distributed generation because the generation is more like random output. Wind and Solar power are clean, free & abundant resources. And there are many challenges associated with the grid because the amount of power generated is variable and uncertain. These technologies have significant financial implications. Integrating distribution generation into distribution systems provides economical, technical & environmental advantages. The technical advantage goals are minimize power loss, improved voltage profile, and improved power quality. The reduction in emissions and pollutant values within the system is a boon for the environment. The goal of economic benefits is to minimize operating costs & make the benefits available to all system participants.

IV. METHODS FOR DISTRIBUTION GENERATION PLACEMENT/OPTIMIZATION TECHNIQUES

A. ANALYTICAL OPTIMIZATION TECHNIQUE

The 2/3 rule is the foundation of the analytical optimization technique for distribution generation location. H.L. Wills [8] proposed this regulation to connect a distributed generation network with a position at the 2/3 point of the line's length and a 2/3 capacity of incoming generation. In order to minimize power losses, Acharya, Naresh et al. [9] proposed an analytical technique expression to find the best placement & amount of distribution generation in the distribution system. The power loss formula oriented analytical approach developed by Wang et al. [10] which is suitable to both meshed and radial distribution system. Hung et al. [11] used a multi-objective index-based analytical approach to find the optimum placement, power factor, and sizing of distribution generation for minimizes power losses.

In order to determine the power factor, the ideal size of distribution generation units at various locations to minimise the power losses, and a technique to determine the optimal placement, Hung et al. [12] created three mathematical approaches utilising three alternative power loss expressions. The optimum size and location of a single distribution generation are determined analytically by T. Gozel et al. [13] using a loss sensitivity factor based on injecting active power. It was suggested by S.H. Lee et al. [14] to use a Kalman filter technique to find the optimal size of multiple distribution generation and an analytical method to find their optimal placements. The analytical solution for determining the optimal size & placement of one and two distribution generations are examined by Costa et.al [15]. A method of analysis, created by N.Mithulananthan et al. [16] to determine the best placement & size for multiple distribution generation. Shaaban.M et.al [17] created power loss formula, voltage sensitivity coefficient & sensitivity index to decrease power loss & improving voltage profile.

B. NUMERICAL METHOD

GRADIENT SEARCH ALGORITHM (GSA): It was introduced by N.S. Rau et al. [18] for the optimal size of distribution generation in meshed network, ignoring & taking into account fault level limitations.

LINEAR PROGRAMMING (LP): To achieve maximum penetration of the distribution generation indicated by A. Keane et al [19] and discover the best location for distribution generation models, the Linear Programming (LP) technique is applied. For the purpose of minimizing load costs, Harrison, G.P et al. [20] proposed an Optimal Power Flow (OPF) based approach.

NON-LINEAR PROGRAMMING (NLP): The distribution generation problem is resolved using Non-Linear Programming (NLP). And a Mixed integer non-linear programming (MINLP) was suggested by Atwa et al. [21] As a method for figuring out how many distribution generators should be located in the distribution network in order to reduce the costs. Kumar et al. [22] were able to determine the ideal number of distribution generations to include in the distribution network in order to reduce cost by utilizing mixed integer non-linear programming. Atwa et al. created MINLP [23] to determine the best location for distribution generation while accounting for load and generation uncertainty from renewable energy sources. S. Pokar et al. [24] used MINLP to select the ideal location for different types of distribution generating units while accounting for changing energy prices.

ORDINAL OPTIMIZATION (OO): This approach was proposed by Zhu, Dan, et al. [25] to choose the best location & size for placement of distribution generation in the distribution network. D. Singh et al. created a comprehensive [26] to address the placement of distribution generation in the distribution network with variable power load.

SEQUENTIAL QUADRATIC PROGRAMMING (SQP): It was suggested by A.M.El- Zonkoly et al. [27] to address the best position for distribution creation without fault level.

TABLE I. TAXONOMY OF THE ANALYTICAL APPROACH

Ref.	Bus System	Objective	Objective Function	Load Model	No. of DG	Variables of DG	Optimization Technique
8	33-bus	Single	Minimization of Loss	Distributed	Single	Size & Location	Zero point analysis and migration zero point
9	30,33,69-bus	Single	Minimization of Loss	Constant	Single	Size & Location	Exhaustive approach and Exact loss formula
10	30-bus	Single	Minimization of Loss	Constant	Single	Size & Location	
11	33-bus	Single	Minimization of Loss	Constant	Single	Size & Location	Exhaustive Load Flow
12	69-bus	Single	Minimization of Loss	Constant	Multiple	Size & Location	Alternative Expression
13	13-bus	Single	Minimization of Loss	Constant	Single	Size & Location	Classical grid search algorithm for various load model
14	30-bus	Single	Minimization of Loss	Constant	Multiple	Size & Location	Kalman filter algorithm
15	34-bus	Single	Minimization of Loss	Constant	Multiple	Size & Location	Analytical Approach in the presence of small generation
16	16,33,69-bus	Single	Minimization of Loss	Probabilistic	Multiple	Size & Location, PF	Improved analytical method
17	13-bus	Multiple	Improving Voltage Profile & Reducing Active Power Loss	Constant	Multiple	Size & Location	Voltage Sensitivity Coefficient & Exact loss formula

TABLE II. TAXONOMY OF THE NUMERICAL APPROACH

Ref.	Bus System	Objective	Objective Function	Load Model	No. of DG	Variables of DG	Optimization Technique
18	6-bus	Single	Minimization of Loss	Constant	Multiple	Size	Gradient Search Algorithm
19	5-bus	Single	Maximizing DG capacity	Constant	Multiple	Size & Location	LP
20	GSP (Grid supply point)	Single	Load Shed Minimization	Constant	Multiple	Size	OPF
21	14,30-bus	Single	Minimization of Energy Loss	Probabilistic	Multiple	Size & Location	MINLP
22	24-bus	Single	Minimization of Cost	Constant	Multiple	Number of DG and Location	MINLP
23	Reliability test system	Single	Minimization of Annual Energy Loss	Constant	Multiple	Size, Location and Type	MINLP
24	30-bus	Single	Minimization of Loss	Constant	Single	Type and Location	MINLP
25	Three interconnected circuit system	Single	Minimization of Loss	Constant	Single	Size & Location	Exhaustive search
26	38-bus	Single	Minimization of Loss	Voltage Dependent	Single	Size & Location	Exhaustive load flow
27	30-bus	Multiple	Minimization of Power Loss Indices, Voltage Profile Index	Voltage dependent	Multiple	Size & Location	SQP

TABLE III. TAXONOMY OF THE META HEURISTIC APPROACH

Ref.	Bus System	Objective	Objective Function	Load Model	No. of DG	Variables of DG	Optimization Technique
28	13-bus	Single	Minimization of Loss	Constant	Multiple	Size & Location	GA
29	16,37-bus	Multiple	Power Loss Index and Voltage Profile	Constant	Single	Size & Location	GA
30	21,43-bus	Single	Cost/Benefit Maximization	Constant	Multiple	Size & Location	GA
31	69-bus	Single	Minimization of Loss	Variable	Single	Size & Location	GA
32	69-bus	Multiple	Maximization of Benefit	Constant	Single	Size & Location	OPF and Hybrid GA
33	34-bus	Multiple	Minimization of Loss	Constant	Multiple	Location	GA
34	14,34-bus	Single	Minimization of Loss	Constant	Multiple	Size & Location	GA
35	-	-	Search Optimal value	-	-	-	GA,TS

36	37-bus	Multiple	Minimization of Loss	Distributed	Multiple	Size & Location	TS
37	30-bus	Multiple	Real & Reactive Power Loss	Voltage Dependent	Multiple	Size & Location	PSO
38	69-bus	Single	Minimization of Energy Loss	Constant	Multiple	Size & Location	PSO
39	33-bus	Multiple	Voltage Regulation, Power Loss Minimization	Constant	Multiple	Size & Location	PSO
40	33-bus	Single	Minimization of Cost	Constant	Multiple	Size & Location	Discrete PSO and OPF
41	30-bus	Single	Minimization of Loss	Constant	Multiple	Size & Location	PSO
42	69-bus	Single	Minimization of Loss	Constant	Multiple	Size & Location	ABC
43	13,33-bus	Multiple	Reliability Enhancement	Constant	Single	Size & Location	ACO
44	33,69-bus	Single	Minimization of Loss	Multi-level	Multiple	Size & Location	SHA
45	6,14,30-bus	Multiple	Minimization of Loss & Cost	Constant	Multiple	Size & Location	Heuristic
46	33,69-bus	Single	Minimization of Loss	Constant	Single	Size & Location	Curve-Filtered Heuristic
47	13,33-bus	Single	Minimization of Loss	Constant	Multiple	Location	Curve-Filtered Heuristic
48	16,33-bus	Single	Minimization of Loss	Constant	Multiple	Location	Sensitivity Index based Heuristic

C. THE META-HEURISTIC SEARCH

The distribution generation problem's optimum placement is best solved via a heuristic approach. These methods deliver the best results. The following describes a few of the heuristic conceptual algorithms.

GENETIC ALGORITHM (GA): It is a search algorithm which is based on the natural selection & natural genetics for finding the size and arrangement of distributional generations. Singh et al. [28] suggested using a Genetic Algorithm oriented approach to determine the amount & location of distribution generation to minimize power losses while taking distributed loads into account. The optimal distribution generation placement problem put forth by D. Singh et al. is solved using GA [29]. Constant power loads and developed scattered loads are taken into account. By maximizing use, Borges et al. [30] applied Genetic Algorithm to locate distribution generation in the best possible location. Genetic Algorithm was added to the predestination approach of his Haesen et al. [31] Designed for distributed generation deployments with multiple targets. Harrison et al. [32] performed a union of OPF & GA for the optimum location of distribution generation. K.H. Kim et al. introduce a hybrid fuzzy target programming and GA. [33] designed with distribution generation locations in consideration. A search that combines Genetic Algorithm & Tabu search was proposed by Gandomkar,M et al. [34].

TABU SEARCH ALGORITHM (TSA): It was established by D. Karaboga., et al. [35]. Solve combinatorial optimization problems. The optimal distribution generation arrangement was overcome by Nara et.al [36] used TSA technique for an event of systematically distribution load.

PARTICLE SWARM OPTIMIZATION (PSO): It is used to identify the size & optimum placement of distribution generation with non-unity power factor concerning the variable power load model developed by El-Zonkely et.al [37] will be an improved PSO was created for the best location of the injecting active power & absorbing reactive power distribution generation type provided by W. Prommee et al [38]. Moradi et al. [39] have presented a mix of GA & PSO. GA optimizes for location, while PSO focuses for size. The OPF of Gomez-Gonzalez et al. is used to complete a discrete PSO [40]. By maximizing the new power stability exponent while determining the ideal distribution generation size, Ishak et al. [41] employ PSO to identify the ideal distribution generation arrangement.

ARTIFICIAL BEE COLONY (ABC): This Algorithm was developed by Abu-Mouti et al. [42] to locate distribution generation in the best possible location and size while minimizing power loss.

ANT COLONY OPTIMIZATION: It is described by Wang et al. [43] implemented to determine the size & position of the distribution generation.

HARMONY SEARCH ALGORITHM (HSA): HSA & Sensitivity Factors are described by Rao et al. [44] implemented to determine the placement of distribution generation.

OTHER HEURISTIC ALGORITHMS, such as traditional iterative methods, have been proposed by S.Ghosh et al. [45] Identify the best placement & size for the dispersal of generations. Using a curve-fitting heuristic, Abu-Mouti et al. [46] designed a test to identify potential buses for the best placement of distribution generations. An analytical technique was created by Nike et al. [47] for locating potential buses for placement of distribution generation. A sensitivity index based heuristic approach was used by Rossetti et al. [48] to locate distribution generation in the best location possible while reconfiguring the network to minimize losses.

V. CONCLUSION

This paper provided an overview of various strategies and optimization methods for distribution generation placement. According to this review article's findings, the majority of studies concentrate on lowering power losses, enhancing system voltage stability, and sizing distribution generation and where it should be located within the distribution system. There are several methods mentioned, including Analytical, Numerical, Meta-Heuristic & Hybrid techniques. Genetic algorithms and different Meta heuristic algorithms are the most preferred and effective methods.

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