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A Comparative Investigation on Optimization Techniques for Optimal Penetration of Distribution Generators in Power System Application

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***Abstract* - In deregulation of power system, different regulatory units, environmental concerns and economic concerns have lead to the penetration of Distributed Generation (DG) in power system. When DGs are penetrated, various parameters like DG technology, optimal size, optimal location, and its impact on various operating characteristics such electrical losses, voltage profile, stability and reliability of power system are to be monitored. The performance of DG penetration depends largely upon the selection of the optimal parameter values. Special optimizing techniques used to evaluate optimal value of parameter in context of heuristic nature of variable. A literature review has been carried out on different optimal technique used to optimize parameter values. The authors have reviewed various definitions related to DG and conventional and non conventional technologies on which DG are based. Various issues regarding DG integration have been discussed. Exhaustive reviews of many optimization techniques have been done for optimal location and size of DG.**
***Keywords:* Distribution Generation, DG Technologies, DG Penetration, Optimization Techniques**

I. INTRODUCTION

The demand of power system is growing exponentially, so power utilities are facing major challenges. Traditionally, utilities have served demand by centralized generation, transmission, and distribution systems. Earlier electric power generation systems utilize the non renewable energy resources [1], such as fossil fuels, hydro, and nuclear for electricity generation. In today's scenario centralized generation is weakening due to the non availability of conventional resources (coal, gas and fuel), environmental concern, trends in deregulation, cost effectiveness, need of systems stability and reliability.

Demand of power is increasing day by day due to which existing transmission line infra-structure is not able to support a large power demand. The demand can be fulfilled either by investing in new transmission system or provide power at the consumer end. Electric power generation penetrated in the distribution systems is known as "distributed" or "dispersed" generation. DG's are small power generators connected near the consumer end or within the distribution network. DG's are emerging as a substitution to the expansion of central generating utilities [2]. DGs can be either being conventional type or non-conventional type. Various reasons for penetration of DG's into distribution systems are reduction in power losses, reduction in the Transmission and Distribution (T&D) costs, it is easier to find sites for small generators, reduction in environmental impacts, improvement in voltage profile, system is more reliable, minimization of emission, reduction in peak load level, and reduction in purchase of power from electricity market.

TABLE I LIST OF OPTIMIZATION TECHNIQUE USED TO OPTIMIZE DG PENETRATION PARAMETER

Name of Technique	Type
Loss Sensitivity Factor	LSF
Hybrid Particle Swarm Opt.	HPSO
Particle Swarm Opt.	PSO
Distribution Network Operator	DNO
Tabu Search	TS
Ant Colony Opt.	ACO
Genetic Algorithm	GA
Optimal Power Flow	OPF
Linear Programming	LP
Non Linear Programming	NLP
Mixed Integer Linear Prgrm	MILP
Simulated Annealing	SA
Multi Objective	MO
Radial Distribution Network	RDN
Power Generation, Uncertainty	PGU
Load Demand Uncertainty	LDU
Non-Dominant Sorting, GA	INSGA
Clustering Differential Evolution	HCDE
Fireworks Algorithm	FWA
Artificial Bee Colony	ABC

The paper is organized as follows: Section 2 presents an introduction to distributed generation along with various definitions associated with DG's, need of DG in power system and different technologies on which DG's are based. Section 3 gives the benefits and applications of

DG. Section 4 deals with technical constraints associated with penetration of DGs in power system. Section 5 comprises of different optimization techniques used for DG placement. The merits and demerits of the techniques have been discussed. Section 6 provides conclusion and planning of distributed generators and future scope for the using distributed generation.

II. DEFINITIONS OF DISTRIBUTED GENERATION

Distributed generators (DG) are small size generators which are located near the consumer end. In literature different terms are used for distributed generation for example the term 'Embedded generation' is used in Anglo-American countries, 'Dispersed generation' term is used in North American countries and 'decentralized generation' [3] is used in Europe and parts of Asia.

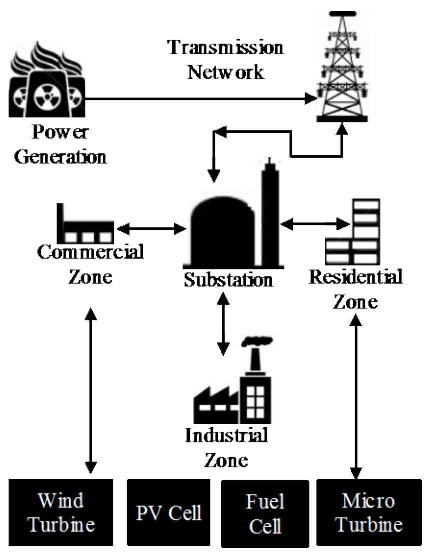

Fig. 1 DG in distribution system

Capacity of DG is from few KW to tens of MW. Figure 1 indicates the penetration of DG in distribution system. According to the literature survey it is identified that distributed generation [4] has been classified on the basis of its capacity, point of location or on the basis of both capacity and location of DG.

A. Need of Penetration of DG

The factors which have significantly increased the penetration of DG can be summarized as:

1. The transmission and distribution (T & D) costs [5] are reduced due to penetration of DG.
2. Advancement in technology has lead availability of DG's ranging in size from 10KW to 15MW=with high efficiency.
3. Installation and site selection of DG is easier.
4. Due to decentralization of the power system it has created large opportunities for new utilities.
5. Constraints on construction of new transmission [6] lines.

B. Overview of Distributed Generation Technologies

Traditionally, diesel generators were used as distributed generators due to their low cost and high reliability. Now a day's due to high fuel cost, environmental issues, electricity market liberalization, needs of highly reliable electricity has led to the improvement in the DG technologies. The DG technologies can be broadly classified as Non-Renewable energy based DG, Renew-able energy based DG and Electrical energy storage, which are not generating sources but facilitate efficient utilization of generated power. Table I provides a brief overview of the most commonly used DG technologies [7] and their module size.

1. Non Renewable DG Technologies

Diesel engine or gas reciprocating engines and gas turbines are the non-renewable DG's sources which are commonly used for generating electricity. Diesel engines are preferably used for back up applications due to low inertia. Due to the advancement in technologies, the reciprocating engines are modified and micro turbines are introduced. Micro Turbines are small combustion turbines with outputs of 25KW to 500KW. They have lower electricity and capital costs as compared to other DG technology costs. MT's comprises of a compressor, combustor, turbine, recuperate, alternator and generator. It is classified by the physical arrangements of the component parts: single shaft or two shaft, simple cycle or recuperated, intercooled and reheated. MT's run at less temperature and pressure and faster speed (100,000 rpm) [8]. According to operating cycles MT's can be classified as Simple gas turbine or Recuperated turbine. In a simple cycle turbine, compressed air is mixed with fuel and burned under constant pressure conditions. Hot gas is expanded through turbine to perform work.

2. Renewable DG Sources

The main reason of popularity of renewable energy sources is its availability in all the regions of the world, contributes towards the improvement of environment, reliable energy and it is ever lasting. Renewable energy [9] based DG are small hydro, biomass, cogeneration, biogas based engines, bio-fuel, solar power, wind power, and geo- thermal energy. Mostly solar and wind energy based DG's are used in distribution power system. The price of electricity produced by conventional sources is lesser than that generated by non conventional sources still renewable energy sources are preferred due to the above mentioned advantages.

Wind Turbine: They can be classified as fixed speed, variable slip, doubly fed induction generator, and full converter wind turbine. In recent years wind energy has tremendous worldwide growth and is considered as one of the leading carbon free technologies. A WT comprises of a rotor, turbine blades, generator, and drive or coupling device, shaft, and the turbine head which contains the gearbox and the generator drive. Wind turbine blades usually are two or three in number each nearly 10–30m long. The wind rotates the windmill-like blades [10], which in turn rotate their attached shaft. This shaft operates a pump or a generator that generates electricity.

PV Cell: Photovoltaic sources comprises of a basic unit called cell. It's of round or square shape. Cell is constructed of doped silicon crystal and connected to form a module. An array is formed to produce electricity by connecting modules. Modules can be connected to provide a variety of power ranges but provides low out power and constraint of geographic and weather is imposed [11]. Solar energy is absorbed by cell from the sunlight. Practically, each cell provides 2–4A based on its size with an output voltage of 0.5V. Normally an array, cells connected in series, provides 12V to charge batteries.

TABLE II LIST OF MOST COMMONLY USED DG TECHNOLOGY

DG Type	Tech	Size
Conventional type	Combined Cycle Gas Turbine	35 KW - 400 MW
	Internal Combustion Engines	5KW- 10 MW
	Combustion Turbines	1 – 250MW
	Micro Turbines	35KW- 1 MW
Non Conventional type	Small Hydro	1 – 100 MW
	Micro Hydro	25 KW –1MW
	Wind Turbine	200 W – 3 MW
	Photovoltaic Array	20 MW- 100 MW
	Biomass Gasification	100 KW – 20 MW
	Geothermal	5 – 100 MW
	Ocean Energy	0.1 – 1 MW
Energy storage type	Fuel Cells, Phos. Acid	200KW – 2 MW
	Molten Carbonates	250KW – 2 MW
	Fuel Cells, Proton Exchange	1 – 250 KW
	Fuel Cells, Solar Oxide	250 KW-5MW
	Battery Storage	0.5 – 5 MW

C. Energy Storage Technologies

It comprises of batteries, fly-wheels, capacitors and other equipments, which stores electrical energy. Various types of energy system are indicated in figure. Since electricity demand is varying over the time these equipments stores energy during low load demand and uses when required. It makes the electricity grid flexible, efficient and reliable [12]. The output energy from PV and wind is reliant on meteorological circumstances existing at that moment. At time of non availability of energy, electrical energy storage can bridge the gap between powers from these sources and load. As it stores excess power during high periods of sun and wind.

Some geographical considerations and exhaustive infrastructure are required to install pumped hydro. Similarly compressed air energy storage (CAES) also has geographical restrictions besides low round trip efficiency. Other technologies such as Super capacitors, SMES and fly-wheel can be rapidly deployed but currently offer restricted capacity [13]. Battery energy storage is one technology that is now attracting considerable interest for autonomous applications as well as for large scale deployment on the grid. It can be used for load following applications thereby dealing with essentially intermittent nature of PV and wind sources.

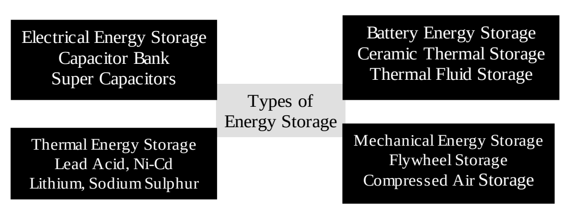

Fig. 2 Different types of Energy storage Facilities

1. Fuel Cell

A fuel cell produces clean electricity by an efficient chemical reaction through electrochemical process and can be utilized in distributed generation. Fuel cells are efficient and pollution free. In this process oxygen is considered as an oxidant and hydrogen as a fuel. In an electrochemical process electricity is generated along with heat and water. In reversible fuel system, production of hydrogen through electrolysis is a prominent feature. Electricity used in process of electrolysis for splitting of water into hydrogen and oxygen is from renewable sources. So, fuel cell can be considered as a DG based on renewable sources. Fuel cells are classified on the basis of electrolyte, operating temperature, and catalysts used in operation. The operating temperature of FC depends on the electrochemical process and this process depends on the electrolyte media used. Some of the fuel cells are proton exchange membrane fuel cell (PEMFC) [14], direct methanol fuel cell (DMFC), alkaline fuel cell (AFC), molten carbonate fuel cell (MCFC) , phosphoric acid fuel cell (PAFC), and solid oxide fuel cell (SOFC).

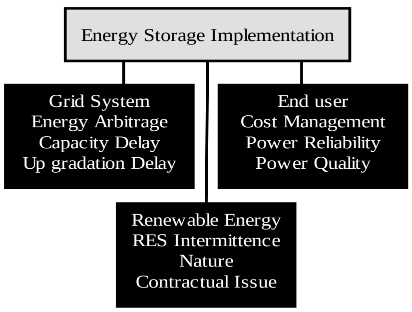

Fig. 3 Energy Storage Facilities Implementation

2. FC's Advantages

1. It converts fuel chemical energy to electric energy with 60% efficiency [15], twice of that of non conventional sources.
2. It operates at lesser noise because only air blowers and water pumps are the moving parts in it.
3. Power generated with cell can be matched with demand due to presence of staking cells which makes them flexible.

3. FC's Disadvantages

1. The ageing factor increases the internal impedance of FC. A power electronic interface is needed to regulate the output voltage.

III. BENEFITS OBTAINED IN DISTRIBUTION SYSTEM DUE TO PENETRATION OF DG

Benefits obtained due to penetration of DG can be reviewed under the various heads. These are:

A. Technical Advantages

1. Improvement in voltage profile of distribution system, Continuity and reliability of the system is enhanced.
2. Minimizing the power quality problems, Reduce power losses in distribution network
3. DGs can be used as on-site standby to supply electricity in case of emergency and system outages
4. DG ranges from few KW to MW large size, can be installed on medium and low voltage distribution network.

B. Economical Advantages

1. Reduced health care cost with the use of RES [16]. Motivation for using non conventional sources of DG's
2. Reduced pollution by using renewable energy sources as DG in distribution system.

C. Environmental Advantages

1. Increased productivity, System security enhanced, Uses existing T & D [17] lines with some up gradation
2. Peak shaving results in low operating cost, Reduction in reserve requirements and related costs.
3. Using the existing T & D lines with some up gradation, Reduced fuel costs due to increased overall efficiency
4. Commonly used DG technologies [18] have lower operation and maintenance cost.

TABLE III BENEFITS OBTAINED BY LOCATING DG AT OPTIMAL LOCATION AND OPTIMAL SIZE

Benefits	DG Placement	Non DG Placement
Minimization of losses	Yes	Yes
Voltage profile improvement	Yes	Yes
Reduction of greenhouse gasses emission	No	Yes
Improvement in reliability	Yes	No
Minimization of contingency	Yes	No
Maximization of system loadability	Yes	Yes
Cost of DNO can be improved	Yes	Yes
Deferring upgrades of power system	Yes	Yes

TABLE IV TYPES OF DG SPECIFICATIONS

DG Type	DG Detail
I	Delivering Active Power Operate at unity power factor Example: Photovoltaic Cell, Fuel Cells, Micro Turbines
II	Deliver only Reactive Power Operate at lagging power factor Example: Synchronous Compensators
III	Deliver both Active & Reactive Power Wide range of Power Factor Example: Synchronous Generator
IV	Deliver the Active power (P) but absorbs reactive power. Operate at lagging power factor Example: Induction Generator

D. DG Applications

Various DG technologies are employed in distribution network for fulfilling the requirements. Some of these applications are discussed below:

Base-load: Distribution network is operated in parallel with the system. Part of energy can be taken or sold and it can take or sell part of the energy by it. The system is working constantly and consumption of electricity is reduced in the network. It supports the grid by improving the system voltage profile reduction in power losses [19] and enhancing the system power quality.

Provide peak load: DG's are utilized to provide electricity in peak durations. This results in reduction of consumers peak demand. The consumers are benefited by this reduction since the cost of energy in this period is usually the highest.

Support to Distribution Network: DG's help in avoiding and resolving congestions in the distribution network at the time of failure of network or supply energy to sensitive load. Energy storage or stand by: DG's are used as backup or stand by at the time of interruption or to supply power for the crucial loads, such as hospitals and industries, at the time of grid outages.

Stand Alone: Power is delivered to remote and isolated areas through DGs [20] instead of connecting to the grid. It is costly to provide electricity through grid to such areas which has geographical conditions.

IV. DG ISSUES AND LIMITATIONS

The performance characteristics of the Distribution network are affected when DG is inserted in it. With the insertion of DG the analysis becomes complex [21] because network is designed for flow of unidirectional power from source to load but with penetration of DG the power flows in both the directions from source to load and from load to source. A single line diagram of a two-bus system with DG is shown in figure [22]. Thus the penetration of distributed generation can affect voltage profile, reactive power in system, and problems in protection. DG has the capability of delivering active power, reactive power or both. Different DG models are given in figure.

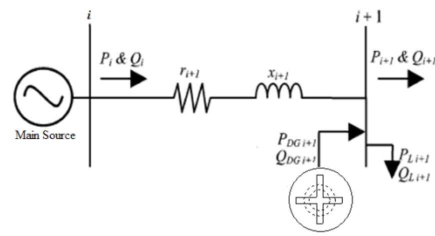

Fig. 4 Single-line diagram of a two-bus system with DG

A. Problems Due To Penetration of DG

Various problems are associated with the penetration of DG in power system are discussed below:

Non Availability of Reactive Power: DG's like traditional wind farms using asynchronous generators do not supply reactive power to the grid. But DG [23] units along with power electronic interfaces are capable of delivering reactive power. DG's can supply and consume reactive power as and when desired

System Frequency: The penetration of DG in the system affects the system frequency and control becomes more complicated.

Voltage Profile: With the installation of DG in power system, the voltage rises in distribution system. This is because of variation in magnitude of power flow in network. No problem exists in penetration the DG's were the voltage is low. Its contradictorily were the voltage is nominal.

Protection Schemes: In generally the distribution networks are radial connected. So the network is designed for flow of power in only one direction from source to load. When DG is penetrated in the network, the flow of power is from load to source also. Due to the bidirectional flow of power the protection system is affected in the following ways:

1. At the time of fault condition, fault current is supplied from power system and DG to the fault point. It may

increase the short circuit current which is more than the capacity of breaker in feeder.

2. The sensitivity of the relay may decrease during the fault condition due to the reduction in feeder current from substation. This is caused because of power flow from DG [24].

Power Quality: Interface with power electronic based equipments is required when RES based DGs are penetrated. It may result in injection of harmonics in the system.

B. Objectives and Consequences of DG Integration

Penetration of DG in distribution network gives lots of advantages, along with many limitations but the system becomes complex. If DGs are included in the system a deep analysis [25] is required to get maximum benefits. Some objectives are discussed in literature are reviewed below:

1. Using Res Based DGS

The deployment of fossil fuel has encouraged the use of RES such as wind energy and solar energy based DGs. The benefits of using RES as DG are to provide pollution free environment and it is also available in plenty. Emission is one of the factors in deciding the optimal size of RES [26] based DG. An analysis is performed by considering carbon taxes, discount rates and cost of fuel for evaluating minimum cost generation portfolio. It can be expected that in near future inclusion of renewable based DG's will increase in power system because of increasing environmental concerns. Still majority of DG allocation is reported in literature focus on placement of conventional generating units. Very few researchers have considered RES based DG's due to the uncertainties associated with them.

2. Need of System Reliability

Distribution generation can provide a reliable power system. It is desired to have a reliable power system because cost of interruption and power outage may have financial affect on the consumers and the utilities. DG is incorporated in the system to serve the purpose of main supply or as a backup in order to avoid extra charges at the time of peak load. The reliability analysis and various assessment methods are developed for generation level as compared to distribution level because generation or transmission level outages are more costly [27].

The benefits of reliability when DG is penetrated in the network are reviewed in. When the fault occurs, the DGs connected to the network are de-energized till the fault is rectified. Thus the reliability of the system is affected. If the DGs are permitted to operate in the island mode than the reliability of the system is increased. To minimize the cost and maximize efficiency, reliability has been chosen as a constraint in optimization model. Genetic Algorithm is used in to determine the optimal wind farm design with aim of maximizing reliability and minimizing the production cost. In formulated a model using iterative method to find the optimal size of hybrid stand alone renewable energy sources for system reliability [28] with minimum cost.

3. Economic Analysis

Economic analysis has been carried out in literature review when RES [29] based DGs are to be integrated in power system as it makes the system costlier. On the other side RES based DGs has the advantage over conventional generating sources when compared in terms of operational costs and environmental benefits. So analysis is required to obtain maximum benefits with minimum cost, when DG is optimally penetrated [46] in the system. Economic analysis is a prominent feature for scheduling the planning. In an objective function is formed in which the ratio obtained due to cost of reduction in losses to the payment for installation of DG is considered.

A multi objective problem is formulated for DG planning and presented a method in which decision taken by system planner permits to choose the most appropriate negotiation, power losses in terms of cost, between expenses in network upgrading [30], cost of energy not supplied, and cost of electrical energy demanded by served customers. The cost of delayed investment however cannot be considered in respect of RES based DGs due to ambiguity in power supplied by them.

The objective function as maximization of social welfare and maximization of profit is formulated as objective function in on the basis of economic analysis. Now a day due to the environmental concern, RES based DGs are preferred for penetration in power system. So a deep economical analysis is required for incursion of renewable sources as DGs in terms of costs and benefits [31].

4. Minimization of System Losses

DG's are integrated in proximity to the consumer end in distribution system which results in significant reduction in electrical losses. If selection of size and location of DG is not optimal, it may increase the losses.

Traditionally, reduction in electrical losses was through capacitor placement since it provided reactive power support to the grid. However, DG has impact on both active and reactive power. Researchers have developed various approaches for loss reduction by finding optimal location and size of DG [32]. Most commonly used method for calculating the power losses is through exact loss formula as follows:

$$P_L = \sum_{i=1}^{N}\sum_{i=1}^{N} \propto_{ij} \left(P_i P_j + Q_i Q_j\right) + \beta_{ij}\left(Q_i P_j - P_i Q_j\right) \cdot\cdot\ 1$$

$$\propto_{ij}= \frac{r_{ij}}{V_i V_j}\cos(\delta_i-\delta_j) \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots \quad 2$$

$$\beta_{ij} = \frac{r_{ij}}{V_i V_j}\sin(\delta_i-\delta_j) \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots \quad 3$$

DGs can minimize power losses of distribution network. DG of capacity 10–20% of the feeder load, allocated in feeders with higher losses could cause reduction of losses [45]. Conventional type DGs are mostly penetrated for loss minimization. Now a day, trend is towards the penetration of non conventional type of DGs. Its impact is to be analyzed. Output of PV cell depends on the availability of sun light but has load variation effectively.

Power produced by wind energy based DGs have been measured with the probabilities of occurrence. The authors have reviewed that due to high intermittent nature of wind energy sources, its impact on losses is minimum. On the basis of literature review it can be accomplished that reduction in line losses with integration of conventional DG [33] sources has been widely studied and not of RES based DGs. Majority of studies fail to acknowledge the impact of intermittency of RES based DGs on line losses.

5. Improvement in Voltage Profile

Traditionally, distribution system is designed in such a manner that power flows from substation to load. These networks are in generally voltage regulated through voltage regulators, capacitors on feeders and tap changing at substation transformers. With the penetration of DG in the system, power flows in reverse direction which may interfere with the methods of regulation used in practice. Integration of DG has a significant impact on voltage profile [34] of distribution system. If DGs are not optimally located it may lead to low or over voltage in the network. This will support a system with low voltage. Voltage can be controlled by reactive compensation with penetration of DG. In DG planning voltage profile has been considered as an objective function [35].

V. DG PLANNING TECHNIQUES

Many benefits like reduction in power losses, improvement in voltage profile, increment in system reliability, power quality at the consumer end is improved and improves the performance of distribution system are obtained when DGS are optimally located and are of optimal size. Various approaches have been developed by the researchers to obtain maximum benefits. A broad classification of optimization techniques is given figure. The detailed analysis of approaches [37] is explained in below in next paragraph. These optimization techniques [38] have been reviewed and compared in this section.

A. Conventional Techniques

Rau *et al.,* have opted classical second order method for finding optimal location of DG to minimize losses [39], reactive power losses and line loadings in network [40]. Acharya et al. [13] had adopted analytical approach to determine the best location and size of DGs in distribution system to minimize the power losses. Authors have used exact loss formula [41] to obtain the solution. Gozel et al. [50] used analytical method with an objective of loss minimization.

Impact of variable DG size has been considered. Authors have considered only conventional type of DGs. Using the same technique Kashem et al. have performed sensitivity analysis [43] to determine size and location for minimization of losses. Gözel and Hocaoglu developed an analytical approach based on loss sensitivity factor for minimizing [42] line losses of power system. For optimal location of DG in radial as well as meshed network, Wang and Nehrir [48] have used two analytical techniques to locate one DG unit, with the size not optimized with an objective of reduction in power losses subjected to voltage constraints [44].

B. Miscellaneous Approaches

Gosh *et al.,* have developed a conventional iterative search approach along with Newton Raphson load flow for DG placement in order to optimize losses and cost using weight factor.

An iterative method that provides an approximation for the optimal placement of DG for loss minimization is proposed in Thukaram et al. [49] have developed a method based on mixed integer non linear programming for finding the most suitable location of RES based DGs to obtain reduction in annual energy losses. In authors have developed mixed-integer linear programming approach for solving the problem of optimal type of DG, size, and its location in radial distribution system.

The objective function minimizes the annualized investment and operation cost. In have developed a non linear programming problem in which single and multiple DGs are allocated in the radial network at optimal place and size with boundary restrictions and equality and inequality constraints are imposed.

C. Intelligent Techniques

The problem of determining the optimal solution for sizing and sitting of DG in distribution network is complex. To obtain accurate and fast results researchers have developed intelligent techniques, inspired by nature. A comparative analysis is done and presented below:

TABLE V COMPARATIVE LIST OF OPTIMIZATION TECHNIQUE FOR DG PENETRATION IN PS APPLICATION

S. No.	Title	Technique	DG	Advantages	Limitations
1	Willis [47], Yr-2000	Analytical approach, based on 2/3 rule	CON, Network: Radial	Minimization of active and reactive power losses, simple and helpful in capacitor placement and impact on feeder flow.	Do not get exact solution under variable load conditions
2	Wang and Nehrir [48]	Technique: Analytical approach	CON & RES, Radial & Meshed	Minimization of losses, Non- iterative in nature, No Convergence problem, Minimum Time	Cannot be directly applied due to the size, complexity and the specific characteristics of distribution systems
3	Thukaram et al. [49]	Analytical Approach	CON, Network: Radial	Minimization of Power and energy losses, repeated power flow is not required	Only determines real power losses
4	Gozel & Hocaoglu [50]	Analytical Method + LSF, Equivalent Current Injection	CON, Network: Radial	Minimize line losses as, the method is easy to implement, faster and accurate	Computationally demanded
5	Elsaiah *et al.*, [51]	Analytical Method	CON, Network: Radial	Minimizing the real power loss, improves voltage profile, No Convergence issue, quickly calculate losses, less computational efforts	Optimal or near optimal solutions are obtained, reactive losses are not considered
6	Naik *et al.*, [52]	Analytical Method	CON, Network: Radial	Minimization of real and reactive power losses Reduction in voltage drop, Fast and accurate method, Easy to implement	Lack of robustness
7	Mahmoud *et al.*, [53]	EA-OPF Efficient Analysis-OPF algorithm	CON, Network: Weekly Mesh	For single DG the minimization of Losses, Less computational time, high accuracy, and No iterations required, Multi-load level and probabilistic	Load models not considered
8	Ganguly and Samajpati [54]	Adaptive GA	RES, Network: Radial, IEEE 33-Node	Minimization of power losses, Maximization of voltage deviation, better than simple GA and DE model, LDU and PGU without any problem-specific knowledge	Complex to Model and Code
9	Zidan *et al.*, [55]	NSGA, DG: RES, Network: Radial, 119 Test System	RES, Network: Radial	Two objectives are to Minimize (OF1, OF2), Incorporates Multiple Constrain and boundary conditions	Hard to Simulate
10	Sheng *et al.*, [56]	INSGA-II	CON, Network: Radial, IEEE 588	Reduction in line loss, Minimization of Voltage deviation, Maximization of voltage stability margin, Global searching capability	Due to many reality constraints best site may not be feasible
11	Abbasi and Hosseini [57]	NSGA-II	CON, Network: Radial Civanlar System	Minimization of power losses and energy not supplied, Minimization of costs associated with DGs, Proper convergence	Complex and time consuming, Difficult to Model
12	Ghadimi *et al.*, [58]	PSO & Fuzzy approach	CON, Network: IEEE 30-Bus Radial	Reduction of loss and power purchased from the electricity market, loss reduction in peak load level, and reduction in voltage deviation, Approach is simple, Fast Convergence	Lack of robustness
13	Kayal and Chanda [59]	MOPSO	CON, Network: Radial IEEE 33-Bus	Minimizing Dis-Co's cost, maximizing the DG owners benefit Reliability, Improve Voltage profile & Efficiency, Easy to code with few equations. Efficient method	Optimized for Client prospective, Distribution Company Consideration is neglected
14	Ameli *et al.*, [60]	Novel Hybrid	CON, Network: Radial IEEE 83-Bus	Minimization of Energy loss, less time is required for obtaining solutions, Robustness is large, Superior Quality	Time consuming as large number of iterations needs to be performed

(Notation Used: Conventional–CON, Renewable Energy Source–RES, Constant Power Source–CPS, Multiple Hybrid Source–MHS)

VI. CONCLUSION

In this paper a detailed review on different issues regarding penetration of distributed generators in power system has been done as it is a complicated matter. Various definitions related to DG and overview of DG technologies has been discussed. Different types of distributed generation, their classification, definitions of DG, and constraints have been reviewed. Economical and operational benefits have been reviewed for penetration of DG in power system. Different technologies are analyzed for their output in terms of benefits and issues. This is found that mostly researchers emphasized on DG penetration using conventional type of DGs in distribution system with the objective of minimization of losses, improvement in voltage profile, enhancement of systems reliability, and cost saves.

But due to growing environmental concerns, sustainable renewable energy sources are penetrated as DGs in power system. Renewable Few researchers have considered energy storage devices as source in distribution system. Numerous approaches have been developed for optimal DG placement and sizing by researchers to obtain optimal solutions for multi objective problems. It's observed that many approaches stuck in local optima in spite of giving a global optimal solution. It's difficult to obtain a solution that optimizes all objectives. A compromise has to be done in accuracy, reliability, and computational time. In this context an ideal approach is yet to be fabricated.

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