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Strategic Integration and Configuration of Distributed Generators Units in Distribution Networks: An Overview

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Abstract:- The distribution system has been paying more and more attention to distributed generation (DGUs) since a few years ago. The main causes of (DGUs) in distribution systems are increased electric demand, a deregulated energy market, and a congested transmission network. These factors ultimately lead to a decline in system performance. There's also an increasing push to cut greenhouse gas emissions. Proper placement and dimensioning are crucial for efficient utilization of DGUs. The system's current performance will be deteriorated and losses would increase due to improper DGUs location and size. However, optimal placement will reduce power loss, increase voltage stability, and maintain a consistent voltage profile in the distribution system. This paper reviews DGUs, the technical developments in DGUs, and several optimisation methods for the optimal placement problem. and size.

Keywords:- *Distributed Generation, Electric Demand, Deregulated Energy Market, Crowded Transmission Network, System Performance, Greenhouse Gas Emissions, Voltage Profile Constant And Optimization Techniques.*

I. INTRODUCTION

The escalating global demand for electricity, along with the pressing need to mitigate greenhouse gas emissions, has spurred a significant transformation in the energy sector. One of the most promising strategies to address these challenges is the strategic integration and configuration of Distributed Generation Units (DGUs) within power distribution systems.(Ogunsina et al. 2021) Distributed generation (DG) refers to the decentralized production of electricity by small-scale power sources located near the point of consumption. This approach stands in contrast to the traditional centralized power generation model, which relies on large-scale power plants and extensive transmission networks.

The integration of DGUs offers numerous advantages, including improved energy efficiency, enhanced reliability, and reduced transmission losses. By generating electricity closer to the end-user, DGUs can significantly reduce the energy lost during transmission and distribution. Moreover, the deployment of renewable energy sources, such as solar photovoltaic (PV) systems and wind turbines, as DGUs contributes to a more sustainable and resilient power grid.(Hemdan and Kurrat 2011)

However, the effective integration and configuration of DGUs in distribution systems present significant technical and operational challenges. Key issues include the optimal placement and sizing of DGUs to maximize their benefits while ensuring grid stability and reliability. Advanced optimization algorithms, such as Particle Swarm Optimization (PSO), have been widely adopted to address these challenges. PSO is a robust and efficient optimization technique inspired by the social behavior of birds and fish, capable of finding near-optimal solutions for complex, multidimensional problems.(Meenal et al. 2022)

Recent studies have demonstrated the potential of PSO in optimizing the allocation of DGUs in distribution networks. (Nasef et al. 2020)These studies emphasize the importance of considering various factors, such as load demand, power losses, and voltage profiles, to achieve the optimal configuration of DGUs . Furthermore, the integration of DGUs requires a comprehensive understanding of the power system's dynamics and the implementation of advanced control strategies to manage the intermittent nature of renewable energy sources.(Khoshayand et al. 2023)

In this context, this paper aims to explore the strategic integration and configuration of DGUs in distribution systems, focusing on the application of PSO for optimizing their placement and sizing. The paper also addresses the key challenges and potential solutions for integrating DGUs, highlighting the benefits of a decentralized power generation approach in achieving a sustainable and resilient energy future.(Alajmi et al. 2023)

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Table 1: Loss Minimization Methods in Distribution System

Methods	DG allocation	Network restructuring	Capacitor Placement
A	•	•	•
B	•		•
C	•	•	•
D	•	•	

KEY: A - Loss Minimization B - Cost Saving C- Voltage Support D – Demand Side Management (DSM)
E- Protection system F - Green Power G - Load Balancing H- Reliability

II. LITERATURE REVIEW

A. Distributed Generation Units

According to (Adeuyi et al. 2020), there are four sizes of DGUs, and the size of DGUs is decided based on how much energy will create.

Table 2: Classification of DGUs According to Capacity

S/No	Details	Capacity
1	Micro DGUs	1 to 5 kW
2	Small DGUs	5 KW to 5 MW
3	Medium DGUs	5 MW to 50 MW
4	Large DGs	50 MW to 300 MW

B. Criteria for DG Classification

Five factors, as illustrated in the following table, can be used to categorise DGUs. Capacity, DGUs Technology, Ownership, Point of Interconnection, and Interconnection Purpose are the factors that need to be considered.

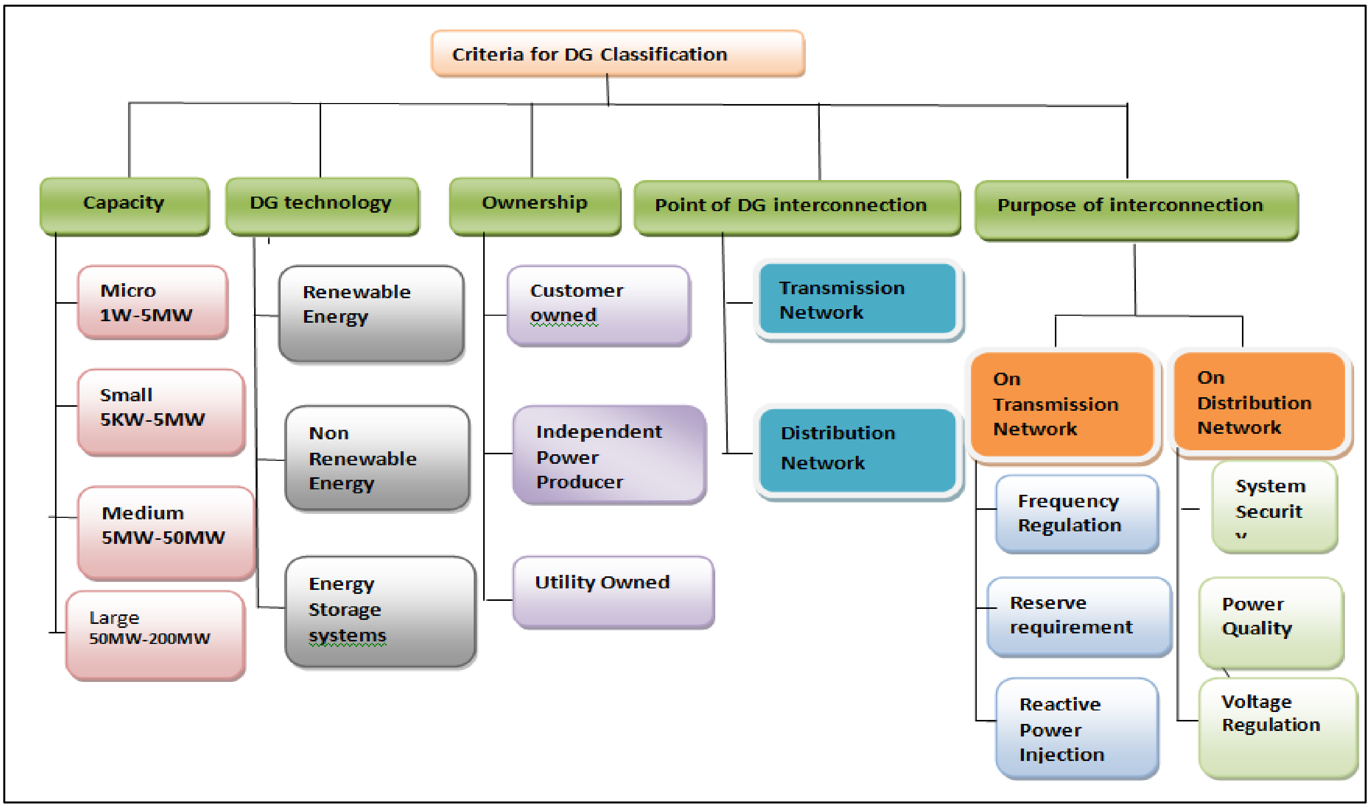

Fig 1: Criteria for DG Classification

C. Potential Benefits of DGUs

➢ *Improved Energy Efficiency*

Distributed Generation Units (DGUs) enhance energy efficiency by generating electricity closer to the point of consumption. This proximity reduces the energy losses that typically occur during long-distance transmission and distribution. Traditional centralized power systems often suffer from significant energy losses due to the resistance in transmission lines, but DGUs can mitigate these losses, leading to a more efficient energy supply chain .(Kazeminejad and Banejad 2020)

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D. Enhanced Reliability and Resilience

The integration of DGUs into the power grid enhances the reliability and resilience of the electricity supply. By decentralizing power generation, DGUs reduce the dependency on single, large-scale power plants, thereby minimizing the risk of widespread power outages. In the event of a failure in one part of the grid, DGUs can continue to provide power to local areas, improving the overall resilience of the electricity network .(Karatepe, Ugranli, and Hiyama 2015)

➢ *Reduction in Transmission and Distribution Costs*

DGUs reduce the need for extensive transmission and distribution infrastructure. By generating electricity near the point of use, they decrease the demand on central power stations and the transmission network. This can lead to significant cost savings in terms of infrastructure investment, maintenance, and operational expenses . (Babu and Swarnasri 2020)

➢ *Support for Renewable Energy Integration*

DGUs often utilize renewable energy sources such as solar photovoltaic (PV) systems, wind turbines, and biomass generators. The integration of these renewable energy sources contributes to the diversification of the energy mix and supports the transition to a more sustainable energy system. By harnessing local renewable resources, DGUs help to reduce greenhouse gas emissions and reliance on fossil fuels .(Bayod-Rújula 2009)

E. Economic Benefits and Local Empowerment

The deployment of DGUs can stimulate local economies by creating jobs and encouraging investment in renewable energy projects. Communities can benefit from lower energy costs and increased energy security. Additionally, the local ownership and operation of DGUs can empower communities to take control of their energy needs and promote sustainable development .(Nasef et al. 2020)

F. Reduction in Peak Load and Grid Congestion

DGUs can effectively manage and reduce peak load demand on the grid. By generating electricity locally during peak periods, they alleviate the stress on the central grid and reduce the likelihood of congestion and overload. This capability is particularly valuable in urban areas with high electricity demand, where DGUs can provide supplementary power to meet peak load requirements .(Rehman, Al-Hadhrami, and Alam 2015)

➢ *Environmental Benefits*

By integrating renewable energy sources, DGUs contribute to significant environmental benefits. They help to reduce carbon emissions, air pollution, and the environmental impact of energy production. The use of DGUs can lead to a cleaner and healthier environment by decreasing the reliance on fossil fuels and promoting the adoption of green energy technologies .(Alajmi et al. 2023)

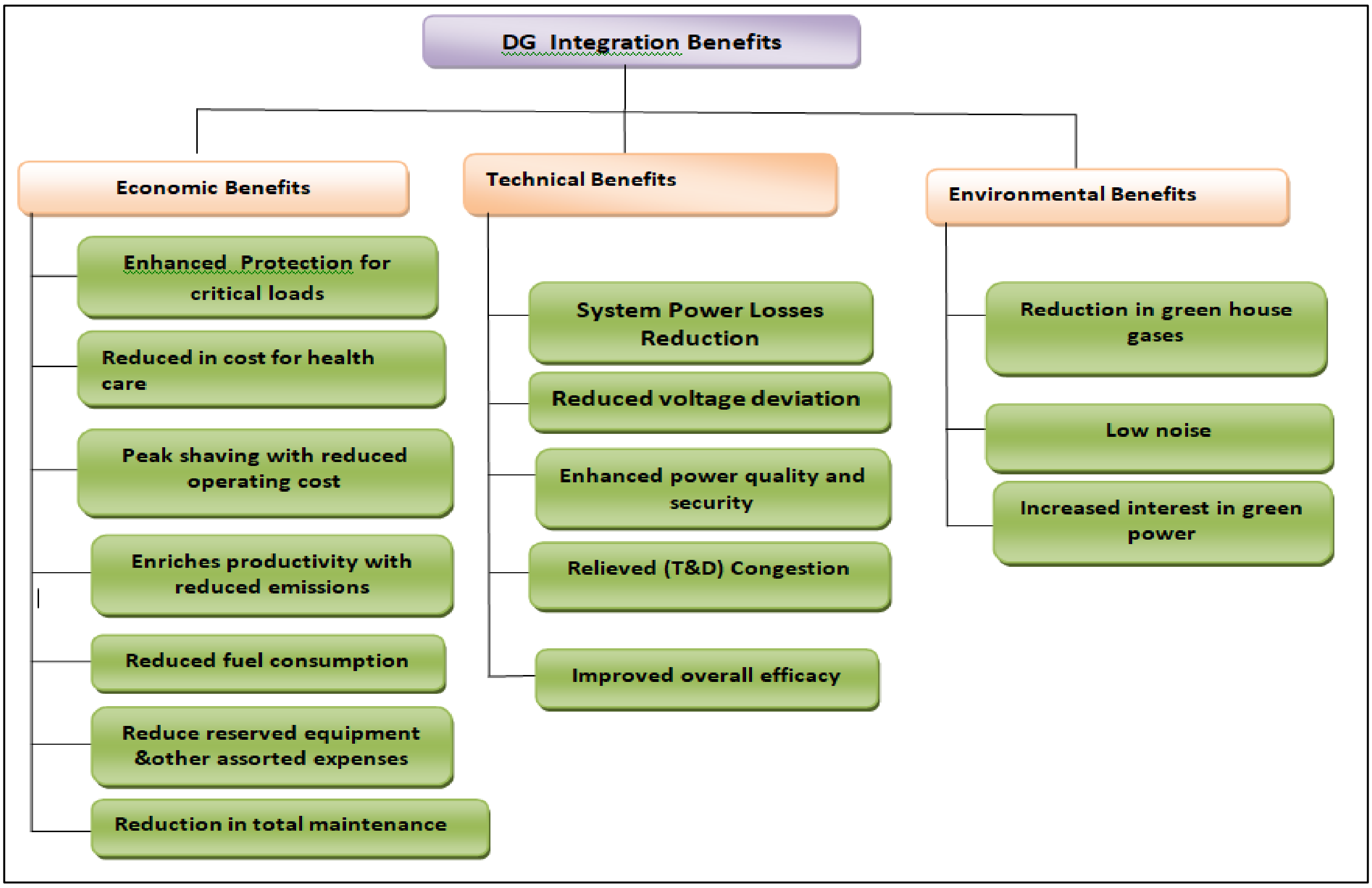

Fig 2: Potential Benefits of DGUs

III. DG APPLICATION IN THE DISTRIBUTION NETWORK

Numerous factors influence the adoption of various distributed generation systems. The following are a few of these factors: Supply for: i) Base load ii) Peak load Support for the distribution network, power supply quality, energy storage, and iv) vi) As backup sources to provide delicate loads with the necessary power. vii) viii) supplying a portion of the load and assisting the grid by enhancing power, decreasing power losses, and improving voltage profile.

A. Different Types and Classification of DGUs

Based on the amount of active and reactive power supplied to the distribution system, DGUs is divided into the following types, as proposed by Petinrin and Shaaban (2016).

Table 3: Classification of DGUs According to Output Power

	Functions	Resources
Type-1	delivering just active electricity	Solar PV Fuel cells
Type -2	delivering only reactive power	Super capacitors Gas Turbine
Type -3	delivering active and absorbing reactive power	Wind power
Type -4	delivering both active and reactive power	Hydro power Cogeneration

Source: (Daly and Morrison n.d.)

B. Distributed Generation Limitations

As mentioned in (Javadian and Haghifam 2013), researchers and distribution network operators encounter the following difficulties and constraints when large-scale DGUs is linked to the grid.

i) Inverse the power flow ii) The ability to react System frequency, voltage levels, protection design, islanding protection, injection of harmonics, and protection design, in that order.

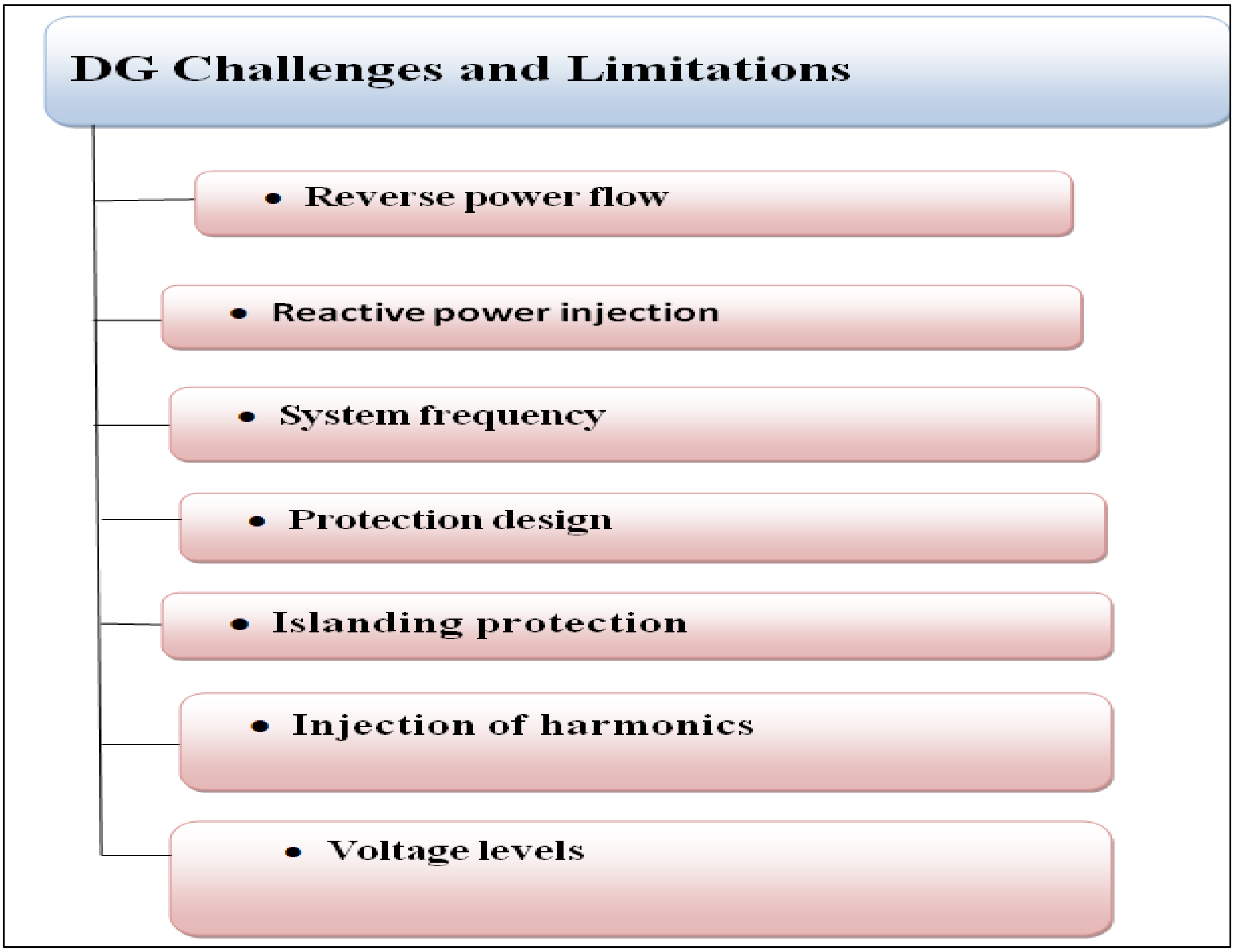

Fig 3: DGUs Challenges and Limitations

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C. Distributed Generation Units (DGUs) Based Technologies

Depending on the load requirements, different DGUs technologies can be given in different applications (Bayod-Rujula 2009). The three main categories of distributed generation technologies are as follows: i) non-renewable DGUs sources (such as gas turbines, combustion turbines, reciprocating engines, and micro-turbines); ii) renewable DGUs sources (such as wind, solar, tidal, geothermal, hydro, and biomass energy).iii) Energy Storage Technology (Batteries, Flywheel, Pumped Storage, Super-capacitors, CAES, SMES)

➢ *Solar Photovoltaic (PV) Systems*

Solar PV systems are one of the most widely adopted DGUs. They convert sunlight directly into electricity using semiconductor materials, typically silicon. Solar PV systems can be installed on rooftops, in open fields, or integrated into building structures. They offer a clean, renewable energy source that reduces greenhouse gas emissions and dependency on fossil fuels. The modular nature of solar PV allows for scalable solutions, making it suitable for residential, commercial, and industrial applications.(Lincy, Ponnavaikko, and Lenin Anselm 2018)

➢ *Wind Turbines*

Wind turbines harness the kinetic energy of wind to generate electricity. They can be deployed as standalone units or in wind farms. Small wind turbines are suitable for distributed generation, providing power for rural or remote areas, farms, and individual households. Wind energy is a renewable and sustainable resource that contributes to reducing carbon emissions and enhancing energy security. Advances in turbine technology have increased efficiency and reduced costs, making wind power a viable option for distributed generation.(Radosavljevic et al. 2020)

➢ *Combined Heat and Power (CHP) Systems*

Combined Heat and Power (CHP) systems, also known as cogeneration, simultaneously produce electricity and useful thermal energy from a single fuel source, such as natural gas, biomass, or biogas. CHP systems are highly efficient, with overall efficiency levels reaching up to 80%. They are particularly beneficial for industries, commercial buildings, and district heating systems where there is a continuous demand for both electricity and heat. By utilizing waste heat, CHP systems reduce energy waste and greenhouse gas emissions.(Nadjemi et al. 2017)Méndez Quezada, Rivier Abbad, and Gómez San Román 2006)

➢ *Microturbines*

Microturbines are small combustion turbines that produce electricity and thermal energy. They are typically fueled by natural gas, biogas, or other renewable gases. Microturbines are compact, reliable, and can be used in a variety of applications, including industrial facilities, commercial buildings, and remote locations. They offer a flexible and efficient solution for distributed generation, with low emissions and the capability to operate in parallel with the grid or in standalone mode.(Shintai, Miura, and Ise 2014)

➢ *Fuel Cells*

Fuel cells generate electricity through an electrochemical process that combines hydrogen and oxygen to produce water, electricity, and heat. They offer high efficiency, low emissions, and quiet operation. Fuel cells can be used in a range of applications, from small-scale residential systems to large-scale industrial installations. They are particularly attractive for distributed generation due to their ability to provide clean, reliable power with minimal environmental impact. Advances in fuel cell technology and hydrogen production are driving their adoption as a viable DGU technology.(Babu and Swarnasri 2020)

➢ *Biomass and Biogas Systems*

Biomass and biogas systems utilize organic materials, such as agricultural residues, animal manure, and organic waste, to produce electricity and heat. Biomass systems convert solid organic matter into energy through combustion or gasification, while biogas systems produce methane-rich gas through anaerobic digestion. These technologies offer a renewable and sustainable energy source that helps manage waste and reduce greenhouse gas emissions. They are particularly suitable for rural areas, agricultural operations, and waste management facilities.(Ellabban, Abu-Rub, and Blaabjerg 2014).

➢ *Small-Scale Hydropower*

Small-scale hydropower systems generate electricity by harnessing the energy of flowing or falling water. They can be installed in rivers, streams, or existing water infrastructure, such as irrigation canals and water supply systems. Small-scale hydropower is a reliable and renewable energy source with minimal environmental impact. It is especially beneficial for rural and remote areas where other forms of electricity generation may not be feasible.(Rehman, Al-Hadhrami, and Alam 2015).

IV. DG SYSTEM CONFIGURATION

To solve optimal issues, this section covers the methodsof DGUs modeling, sensitivity factor analysis, formulation of the optimization issue, load flow, and optimization algorithm implementation.

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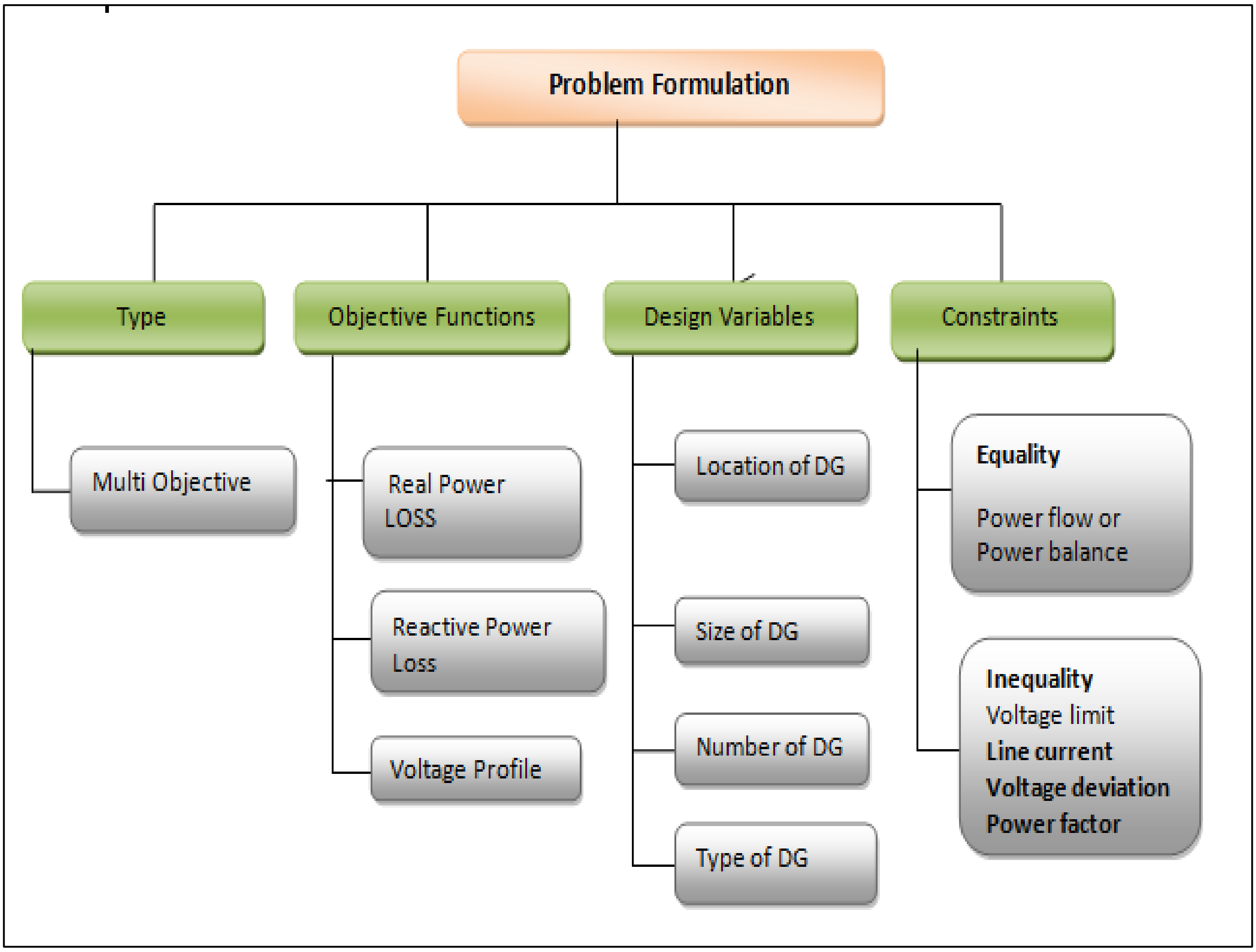

Fig 4: Components of System Formulation

Table 4: Modeling of DGs

DGUs Technology	Type of Model	Physical Examples
Synchronous Generator	Variable Reactive power Model	Combustion turbines, small hydro turbines, reciprocating engines
Induction Generator	Reactive Power Consumption Model	Wind generators, Squirrel induction generators
Asynchronous Generator	Constant Power Factor Model	Solar PV, Fuel cells

- *Sensitivity Factor Analysis*

A power system's sensitivity factor analysis aids in determining which buses are weak under specific loading circumstances. In distribution system voltage profile and loss analysis, two types of sensitivity factors are typically utilised. They are

- Loss Sensitivity Factor (LSF) and
- Voltage Sensitivity Factor (VSF).

- *Mathematical Modeling of the system*

Considering a simple two bus radial distribution System connected with load which is depicted in Figure below (Mohammadi and Faramarzi 2012)

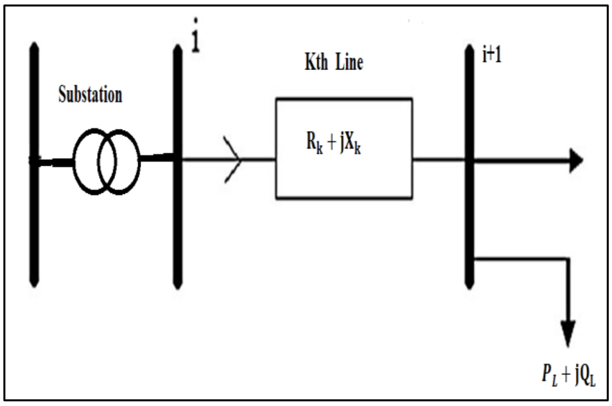

Fig 5: A Simple Two-Bus Distribution Line with Connected Load

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➢ *Loss Sensitivity Factor for Distribution Networks Connected with Distributed Generation Units*

The integration of Distributed Generation Units (DGUs) into distribution networks has been a prominent strategy for enhancing the efficiency, reliability, and sustainability of power systems. One critical aspect of this integration is understanding the impact of DGUs on power losses within the network. Loss sensitivity factor (LSF) analysis provides valuable insights into how the placement and sizing of DGUs influence power losses.(Rajaram, Kumar, and Rajasekar 2015)

➢ *Introduction to Loss Sensitivity Factor*

The Loss Sensitivity Factor (LSF) measures the sensitivity of power losses in a distribution network to changes in the location or capacity of DGUs. By identifying the areas in the network where DGUs can significantly reduce losses, planners can optimize the integration of these units to improve overall system efficiency.(Suresh Kumar Sudabattula, Muniswamy, and Suresh 2019)

➢ *Mathematical Formulation*

The LSF for a distribution network can be derived using power flow equations. Let P_{loss} represent the total real power losses in the network, and P_{DGU} denote the power injected by a DGU. The LSF_i for a DGU located at bus iii is given by:(Aman et al. 2022)

$$LSF_i = \frac{\partial P_{loss}}{\partial P_{DGU,i}} \tag{1}$$

This formulation helps determine how incremental changes in the power injected by the DGU at bus iii affect the total power losses in the network.

➢ *Application in Optimal DGU Placement*

In the context of optimal DGU placement, LSF analysis helps identify the most effective locations for DGUs to minimize power losses. By calculating the LSFs for various potential locations, planners can prioritize sites where the deployment of DGUs will yield the highest reduction in losses. This method ensures that the benefits of DGUs are maximized in terms of loss reduction.(Nataraj et al. 2019)

V. CASE STUDY: LOSS SENSITIVITY FACTOR ANALYSIS

➢ *Consider a Radial Distribution Network with Multiple Potential Sites for DGUs. The Following Steps Outline the Process for LSF Analysis:*

- Power Flow Analysis: Perform a base case power flow analysis to determine the initial power losses in the network.
- Sensitivity Calculation: Calculate the LSFs for each potential DGU location using the partial derivative of power losses with respect to the power injected by DGUs.
- Ranking of Locations: Rank the potential DGU locations based on their LSF values, with higher values indicating greater potential for loss reduction.
- Optimization: Deploy DGUs at the top-ranked locations and re-evaluate the power losses to ensure optimal placement.(Rahmann and Castillo 2014)
- Benefits of LSF Analysis: LSF analysis offers several advantages in the context of DGU integration:

✓ Targeted Loss Reduction: By focusing on locations with high LSFs, planners can achieve significant reductions in power losses with minimal investment.

✓ Enhanced System Efficiency: Optimally placed DGUs improve the overall efficiency of the distribution network, leading to lower operational costs and improved reliability.

✓ Informed Decision-Making: LSF analysis provides a quantitative basis for making informed decisions about DGU placement and sizing, leading to more effective integration strategies.(Abu-Mouti and El-Hawary 2011)

➢ *Challenges and Limitations*

Despite its benefits, LSF analysis has certain limitations:

- Model Accuracy: The accuracy of LSF analysis depends on the precision of the power flow model used. Simplified models may not capture all the nuances of the actual distribution network.
- Dynamic Conditions: LSFs are typically calculated based on static conditions. However, the actual impact of DGUs may vary under dynamic operating conditions, requiring more complex analysis techniques.(Tian, Zhang, and Weng 2020)
- Multiple Objectives: In practice, planners often need to consider multiple objectives (e.g., voltage stability, reliability) in addition to loss reduction. Balancing these objectives can complicate the optimization process.(Manafi et al. 2013)

Thus Loss Sensitivity Factor analysis is a powerful tool for optimizing the placement and sizing of Distributed Generation Units in distribution networks. By focusing on locations with high LSFs, planners can achieve significant reductions in power losses, enhance system efficiency, and make informed decisions about DGU integration. Despite its limitations, LSF analysis remains a valuable method for improving the performance of modern distribution networks.

➢ *Identification of Optimal Locations Using Loss Sensitivity Factors*

- DG placement optimal locations are determined by taking into account the DGUs placement optimal locations are determined by taking into account the voltage magnitudes normalised by assuming a minimum voltage value of 0.95 at these buses, which is known as the voltage sensitivity factor (VSF).
- The LSF determines whether compensation is required, while the VSF determines the priority.

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- The buses are kept in a vector based on their placements, and the loss sensitivity factors are computed for each bus from the load flows. This arrangement of factors results in a decreasing order.
- The buses with VSF (i) 1.05 are chosen as the ideal sites for the installation of DGUs to minimize actual and reactive power losses and concurrently increase the voltage profile, hence increasing the power-providing capability.
- The maximum value of the normalized voltage at the buses where compensation is needed is set at 1.05.

The losses of each feeder line segment may then be added up to get the overall power losses of the feeder, P_(T, loss) and Q_(T,loss), which are as follows:

$$P_{T,loss} = \sum_{I=1}^{N} \frac{R_i}{V_i^2}(P_i^2 + Q_i^2) \quad (2)$$

$$Q_{T,loss} = \sum_{I=1}^{N} \frac{X_i}{V_i^2}(P_i^2 + Q_i^2) \quad (3)$$

When the DG is integrated to the distribution system as shown in Figure 3, the power loss equations derived above can be modified as:

$$\mathrm{P_{T,loss}} = \frac{\mathrm{R_i}}{\mathrm{V_i^2}}(\mathrm{P_i^2} + \mathrm{Q_i^2}) + \frac{\mathrm{R_i}}{\mathrm{V_i^2}}(\mathrm{P_G^2} + \mathrm{Q_G^2} - 2\mathrm{P_iP_G} - 2\mathrm{Q_iQ_G}) \quad (4)$$

$$\mathrm{Q_{T,loss}} = \frac{\mathrm{X}}{\mathrm{V_i^2}}(\mathrm{P_i^2} + \mathrm{Q_i^2}) + \frac{\mathrm{X_i}}{\mathrm{V_i^2}}(\mathrm{P_G^2} + \mathrm{Q_G^2} - 2\mathrm{P_iP_G} - 2\mathrm{Q_iQ_G}) \quad (5)$$

➢ *Voltage Deviation Index*

Adding DGUs to an already-existing radial network increases the voltage at each node as they contribute locally to the load's energy consumption, which lowers feeder losses and raises the voltage deviation.

As stated below, the Voltage Deviation Index (VDI) for bus I may be calculated using mathematical modeling of the flow of electric power and the reduction of power losses on power lines (Karaboga and Akay 2009).

$$\mathrm{VDI_i} = \sum_{\mathrm{i}}^{\mathrm{NB}} |1 - \mathrm{V_i}| \quad (6)$$

Where V_i is the voltage at the i^{th} bus in pu and NB is the number of buses

Equations 2 and 3 illustrate how the goal function is therefore defined as the reduction of the related losses and the voltage variation. In this sense, it will be methodically established where the best place to put the necessary DGUs unit and how big it should be to minimize power losses and voltage deviations from the nominal value while still staying within the bounds of the system. Minimize ;

$$\mathrm{F} = \sum_{\mathrm{i=1}}^{\mathrm{N}} \mathrm{W_1} * (\mathrm{P_{loss(i,i+1)}}) + \sum_{\mathrm{i=1}}^{\mathrm{N}} \mathrm{W_2} * (\mathrm{Q_{loss(i,i+1)}}) + \sum_{\mathrm{i=1}}^{\mathrm{N}} \mathrm{W_3} * (1 - \mathrm{V_i})^2 \quad (7)$$

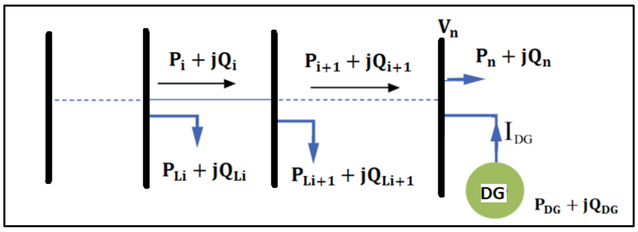

Fig 6: Distribution System with DGUs.
(Raoofat and Malekpour n.d.).

VI. LITERATURE SUVERY

The primary purposes of DGUs in distribution systems are to reduce power losses, optimize voltage profile, and boost system dependability and voltage stability. Numerous techniques, including analytical, numerical, and artificial intelligence-based techniques, have been used to optimize the size and position of the DGUs in order to boost system performance.

A. *Analytical Based Methods*

The position and size of DGUs in distribution networks are optimized despite the numerous shortcomings of the analytical approaches. This is due to their ease of use and the ease with which their logical analysis may be followed.

- To reduce losses, an analytical method has been given (Elnashar, ElShatshat, and Salama 2014) to determine the ideal position for a single DGUs in both radial and loop systems. However, Mena and Martín García (2015) suggested a passive way to get around the distribution voltage increase barrier and lessen the effect of DGUs reactive power demand on the transmission system voltages, allowing for the connection of additional DGUs.
- A linear programming approach was used to calculate the tap setting of the gearbox transformer and the fixed power factors of the generators.

B. *Computational Methods*

Computational approaches are another class of techniques used to optimize the placement and dimensions of DGUs in a power system. These approaches are quick in comparison to other groups of techniques, but they have the downside of being complicated, making it difficult or even impossible to replicate the results.

- Le et al. (2007) tackled the problem of maximizing distribution group design about the size and placement of DGUs to minimize line losses within distribution networks. Their optimization process evaluated the compatibility of several generating methods based on the degree of power loss reduction and DGUs cost. It was based on the Sequential Quadratic Programming (SQP) algorithm. (Volkanovski, Čepin, and Mavko 2009) proposed a simulated annealing technique and deterministic initialization-based strategy for the best reactive-power adjustment in distribution networks. Their findings supported the necessity of implementing and refining reactive power compensation in distribution networks. The available transfer capacities of the

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connectors were enhanced, losses were reduced, and bus voltages were improved. The distribution network's reduced peak load and energy losses produced significant annual savings.

C. Artificial Intelligence-Based Methods

The most promising techniques in artificial intelligence are gradually replacing the analytical and computational optimisation approaches. This is due, among other advantages, to the artificial intelligence approaches' lack of gradient basis, which makes them less likely to become stuck in a local minimum. Additionally, it is simple to replicate the outcomes of the artificial intelligence optimization methods. Among the techniques for artificial intelligence are

D. Genetic Algorithm (GA) Based Optimization Techniques

One of the most often utilized artificial intelligence optimization methods, genetic algorithms (GAs), has been documented in some academic works. Several writers have optimised the size and placement of DGs in power networks using GA.

- To ascertain the size and placement of DG units, Padullés, Ault, and McDonald (2000) employed a Genetic Algorithm (GA) based approach. They have tackled the issue in terms of cost, taking into account that the cost function may cause a variance in the precise size of the distributed generation unit at an appropriate position. Although it is slow to converge and requires a lot of processing power, it consistently yields a nearly ideal answer.
- Using a Real-Coded Genetic Algorithm (RCGA), Hooshmand and Ataei (2007) found the best location for capacitor banks in imbalanced distribution systems with meshed/radial layouts. Capacitors, both fixed and switching, were best used for reducing losses and managing distribution system voltages.
- To find DGUs in radial distribution networks with the least amount of system losses possible, Shukla et al. (2010) employed GA. To minimize actual power loss while adhering to equality and inequality requirements, the problem is stated as an optimization problem, and GA is used to find the solution. The active power loss sensitivity to real power injection through DGUs is used to determine the optimal position. They showed that the advantage grows when there are more sites inside a given area.
- Beyond which it is uneconomical. This formulation considered active power losses only.

E. Particle Swarm Optimization (PSO) Related Techniques

Particle Swarm Optimization (PSO) techniques have also been used in several open literature by different authors in the optimization of DGUs location and size in a power system with the aim of reducing system power losses and improving voltage profile.

- (Zou et al. 2009) proposed a method for voltage support in distribution systems by employing DGUs and shunt capacitors. The target voltage support zones were identified using a numerical/analytical method thus reducing the large search space. The strategic placement of DG units and shunt capacitors is proposed for overall voltage support and power loss reduction by minimizing the investment cost for DG units and shunt capacitors using PSO.
- (Ziari et al., 2010) used a Hybrid PSO (HPSO) to design DG and capacitor banks optimally to reduce line loss and reliability expenses as well as the investment cost of electricity networks. To lower the chance of catching in the local minimum, crossover and mutation operators alter the PSO. In their study, they took into account just actual power losses.
- Singh and Gyanish (2018) introduced an approach that uses PSO to minimize power loss while preserving the voltage profile and stability margin for the best possible placement and size of numerous distributed generators. Their findings demonstrated that, when compared to other classical and analytical approaches, the strategy performed better or at least similarly for the single DG placement problem.
- Nevertheless, some of the restrictions were broken by where the third DGUs were placed.
- (Varesi 2011) suggested a PSO-based method for the best distribution of DGUs in the power system to aid in the improvement of the voltage profile and decrease of power loss. PSO was suitably integrated with the load flow algorithm to ascertain the ideal quantity, kind, dimensions, and placement of DGUs. In his work, he only took two kinds of DGUs into account.
- Using several STATCOM controllers and dynamically altering their parameter settings, Mancer et al. (2012) suggested an efficient variation of PSO to solve the multi-objective optimum reactive power flow (ORPF) based flexible AC transmission system (FACTS). Voltage variation and power loss were the two objective functions taken into consideration.
- Zare, Abapour, and Jalali 2014 developed A PSO-based optimum distribution system DGUs placement strategy that takes voltage stability and short circuit level improvement into account . In an attempt to more realistically assess a power system's voltage stability margin for a given operating condition and network topology, they looked into the voltage stability assessment while taking into account uneven regional load growth patterns and the economical dispatch of the online generation units.
- In order to simultaneously determine the ideal position and size of DGUs and shunt capacitor banks in power networks, (Aman et al., 2013) employed the Particle Swarm Optimization (PSO) technique. Radial distribution networks consisting of 12, 30, 33, and 69 buses were used to evaluate the suggested method. The result showed that the proposed methods had significantly reduced the power system losses as well as improving the overall loading factor.

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Table 5: Summary of the Reviewed Work

Research Work	Objectives	Techniques/Methods used	Gaps
(Ziari et al. 2010)	Reduction of line losses, increase of system dependability, and voltage profile enhancement	Hybrid Discrete Particle Swarm Optimization (HDPSO)	The solution could become trapped in a local minimum.
(Varesi 2011)	Determination of optimal type, location & size of DGUs to enhance voltage profile and minimize power in distribution line	Particle Swarm Optimization (PSO)	The solution could become trapped in a local minimum.
(Zou et al. 2009)	Improvement of Voltage Profile &Minimization of power loss	Distribution Power Flow Solution Algorithm	only take into account active power loss
(Volkanovski, Čepin, and Mavko 2009)	Minimization of power losses	Optimal Power Flow(OPF) Algorithm &Improved Harmony Search (HIS)	It's possible for premature convergence to happen.
(Abu-Mouti and El-Hawary 2011)	Minimization of real power loss,THD and voltage profile improvement	Particle Swarm Optimization & Sensitivity Analysis	ignored reactive power losses
(Mancer et al. 2012)	Reduction of power loss and node voltage deviation in the network	Adaptive Genetic Algorithm (AGA)	more rapid convergence and the ability to reach the global optimum
(Rehman, Al-Hadhrami, and Alam 2015)	Reduction of power loss and enhancement of voltage stability	Bat Algorithm	Potential trapping of the solution in a local optimum
(Borges and Falcao 2006)	Loss index Reduction and Voltage Stability Index Enhancement	Sensitivity Analysis and modern Interior Point Method	only focused on wind energy as the sole DGUs
(De Souza et al. 2013)	Active Power loss reduction and improvement of the system's voltage stability margin	Genetic Algorithm	Operational expenses, DGUs investment, and reactive power loss
(Esmaili 2013)	Minimization of power loss	Langrang Multiplier Method (LMM)	Reactive power loss was not taken into account.
(Katamble et al. 2019)	Total power loss reduction and enhancement of system's voltage profile	Fuzzy logic method and Analytical Approach	Just one DGUs location and size were taken into consideration.
This work	Optimal integration of DGUs units in LVAC & MVAC	Particle Swarm Optimization	much worse results when attempting to locate the global optimum.

VII. CONCLUSION

This article presents research challenges and the most recent developments in DGUs technology, which benefit DGs. Furthermore, a summary of study has been done for DG in the distribution system. According to the research, it must be ideally situated with appropriate seating and size in order to receive the most compensation from DGUs.

In order to meet the system restrictions, several researchers have contributed to this topic using various objective functions and techniques. Additionally discussed and provided are the benefits and drawbacks of various approaches to the DGUs placement and size dilemma. Lastly, problems and research questions are raised.

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