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Optimal Integration Of Renewable Distributed Generation Into Radial Distribution Systems

A project

**Submitted to the College of Engineering/University of Babylon as
Partial Fulfillment of the Requirements for the Degree of Higher
Diploma in Electrical Engineering.**

By

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بِسْمِ اللَّهِ الرَّحْمَنِ الرَّحِيمِ

(إِزْرَبِكُمُ اللَّهُ الَّذِي خَلَقَ السَّمَاوَاتِ وَالْأَرْضَ فِي سِتَّةِ أَيَّامٍ ثُمَّ اسْتَوَى عَلَى الْعَرْشِ
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Dedication

*To everyone who works on pleasing God
and human beings Service.*

Wael Shakir

2022

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Foremost, I will repeat my lonely prayer "please, my Allah don't leave my hand even if I left your hand". I would like to express my gratitude and thanks to ALLAH, who answered my prayers and bestowed upon me abundant blessings, including the ability to complete my study.

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Abstract

Integrating distributed generation units (DGs), such as photovoltaic and wind energy sources, into distribution systems has become an unavoidable necessity due to many technical and economic advantages and. For instance, the distribution system performance can be improved by optimally choosing DG placement and sizing, which improves voltage profile, reduces active power losses, and releases line loading. Inappropriate placement and sizing of DGs with an uncontrolled high penetration level of DGs into distribution systems might lead to various operational challenges, such as violating acceptable voltage limits, increasing line losses, excessive feeder loading, and protection failure, unidirectional power flow, equipment thermal ratings, and fault current levels. This work efficiently integrates DGs into distribution systems using an optimal method to investigate the DGs' best placement and sizing. The optimization technique proposed herein is based on genetic algorithms and a loss sensitivity factor to minimize distribution system losses and improve voltage profile considering the presumable technical constraints. Several cases are conducted to show the impact of DG location and size on the distribution system performance. The obtained results reveal that using the loss sensitivity factor can expedite finding the optimal solution for the genetic algorithm. This work is performed on the standard IEEE 69 bus network using MATLAB.

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List Of Symbols:

Symbols	Definition
A	Cross-sectional area
Ω_C	Crossover probability
I_L	Load current
\bar{I}_L	Phase current
I_{Line}	Line current
I (mn)	Branch current
I_i^r	The real part of the equivalent current injection at the k-th iteration for i-th node.
I_i^K	The equivalent current injection at the k-th iteration for i-th node.
I_i^i	The imaginary part of the equivalent current injection at the k-th iteration for i-th node.
I_i	I-th node equivalent current injection.
L	Line length
N_{dg}	Number of DG units
P_i	The real power at i-th node
P_j	Active power supplied at bus j
$P_{loss(i,j)}$	Active power loss between bus i and j
P_{DG}	Active power of DG
p_{DG}^{min}	Minimum active power of DG
p_{DG}^{max}	Maximum active power of DG
η_{pop}	Population size
Q_j	Reactive power supplied at bus j
$Q_{loss(i,j)}$	Reactive power loss between bus i and j
Q_{DG}^{max}	Maximum reactive power of DG
Q_{DG}^{min}	Minimum reactive power of DG
Q_i	The reactive power at i-th node
R_i	The resistance of i-th branch
R_{ij}	Resistance of line connected between bus i and j

ρ	Resistivity
S_{ij}	Apperent power in line between bus i and j
S_{max}	Apperent power at its maximum in line
S_i	The complex power at i-th node
V_i	I-th node voltage.
VD_{max}	Voltage Division allowable in DN
V	Substation Voltage
V_{Line}	Line voltage
V_L	Load voltage
V_{min}	Minimum Voltage
V_{max}	Maximum Voltage
$V(n)$	Voltage at node n
$V(m)$	Voltage at node m
$ V_j $	Magnitude of voltage receiving bus j
V_j	Voltage of receiving bus j
V_S	Source voltage
X_{ij}	Reactance of line connected between bus i and j
$Z (mn)$	Branch impedance
Z_{ij}	Impedance of line connected between bus i and j
δ_i	Angle at bus i
δ_j	Angle at bus j

List of Abbreviations:

Abbreviations	Definition
DG	Distributed Genration
DGs	Distributed Generations
DN	Distributed Network
DNs	Distributed Networks
ECI	Equivalent Current Injuction
GAs	Genetic Algorithms
IEEE	Institute Of Electrical And Electronics Engineers
Kw	Kilo Watt
KVA	Kilo Volt Ampere
LSF	Loss Sensitivity Factor
Loc	Location
NB	Number Of Buses
PEV	Plug In Electric Vehicle
RES	Renewable Energy Sources
RDN	Radial Distribution Network
VD	Voltage Division

CHAPTER 1

1.1 Introduction

The distribution network (DN) is continually confronted with increasing load demand. As a consequence of this ever-increasing load, the network is experiencing increased stress as well as a decrease in voltage [1]. The voltage at the distribution network's nodes (nodes) decreases as distance increases from the substation, which is a characteristic property of distribution networks. This drop-in voltage is almost entirely attributable to a deficiency in the quantity of reactive power. Even in certain industrial areas with essential loads, it has the potential to cause the voltage to drop. Therefore, reactive compensation is necessary in order to both enhance the voltage profile and prevent voltage collapse [1-2]. The power utilities have been obliged to decrease the losses that occur at the distribution level. Reducing these losses may be accomplished by a variety of different configurations, such as network reconfiguration, placement of shunt capacitors, and placement of distributed generations [1-3].

The common knowledge is that losses in the DN are higher as compared to those of other networks. When compared to transmission levels, the X/R ratio for distribution levels is much lower, which results in significant power losses and a reduction in the amplitude of voltages [1-7]. The DGs satisfy a portion of the loads, which results in a decrease in the apparent power in the branches. Installing DGs on any DNs will assist in lowering system losses, improving the voltage profile of the DN, the networks' stability, and the power factor of the networks [5-8]. Under the smart grid concept, the DGs technologies are now essential solutions for DNs [5, 9]. These technologies can be broken down into two groups: i sources of energy that don't use fossil fuels (RES) and (ii) sources of energy that do. DGs that use

renewable energy sources (RES) include wind turbines, solar panels, biomass, geothermal, small hydro, etc. [10-34].

The environment, the economy, and technology all play a big role in how DG develops. As part of the Kyoto agreement on climate change, many steps have been taken to cut carbon emissions, and as a result, the number of DGs in distribution systems is on the rise [35]. The presence of the DG in distribution networks is a huge technical and safety challenge [36–37]. So, it is very important to look at how DG affects the technical side of DN. The DG needs to be linked in distributed systems so that the power quality and reliability don't go down. It is very important and hard to figure out how DG affects the technical side of power networks. If DG isn't put where it needs to be and isn't big enough, it can increase fault currents, cause voltage changes, reduce or might increase losses, raise capital and operating costs, and so on [38].

1.2 Problem Formulation

The proposed algorithm's primary objective is to reduce the amount of power that is wasted (P_{loss}) in a certain electrical network satisfying all constraints of the power system and DG by determining the optimal locations using the loss sensitivity factor and the size of DG units using genetic algorithm. The issue of DG allocation and size should be studied cautiously. If DG units are connected in wrong locations, system losses may rise, leading to higher costs. Unsuitable DG sites or sizes may result in larger system losses than those in the present network.

1.3 Literature Review

The technology behind these renewable-powered generators is advancing in order to make them easier to use. Traditional centralized generating methods are compared to DG technologies in terms of operating efficiency and cost. DG allocation in a distribution system is essentially a complex combinatorial optimization problem that necessitates concurrent optimization of multiple objectives [39], such as making the system losses lower, voltage magnitudes within the limits, and less carbon emanation. There are now many researchers working on the issue of DG allocation.[40 - 50] . Erlich et al. [5] describe a technique for controlling passive power (reactive power) from a collection of DGs scattered over radial distribution networks. Kashem et al. [6] proposed a new solution based on the sensitivity factor for changing in system losses due to using DGs. The ideal position of DGs was predicted in [51] by determining the V-index. Optimization is the practice of attempting to discover the optimum answer from a collection of accessible alternatives. In the DG allocation issue, DG sites and sizes must be optimized to provide the most cost-effective, efficient, and technically sound distribution system. There are numerous nodes in a general distribution system, making it difficult to discover the right DG position and size by hand. Deterministic algorithms have been utilized among the many solution methodologies. [52] presents an analytical technique for determining the appropriate position of DG. Recent investigations, on the other hand, have largely employed heuristic algorithms, such as fuzzy and Genetic Algorithms (GA) [43-44]. DG is strategically arranged to minimize losses and enhance voltage profile. Sudipta, Ghoshal, and Saradindu used the Newton Raphson approach to evaluate the appropriate DG size and location in a network [53]. In their study, Koutroumpezis and Safigianni identified the optimal allocation of the highest feasible DG penetration in a distribution network bus at specified connection points, in order to prevent technical problems without

modifying the network topology [54]. Many studies [55–57] have employed evolutionary computational approaches to discover the best DG location. Sukla, Singh, and Naik use GA to estimate the ideal position of distributed generation for minimizing system losses in radial distribution networks [56]. Carmen and Djalma have used GA to optimize distributed generation for dependability, losses, and voltage enhancement. Nara utilized the Tabu search technique to determine the best location for a distributed generator [57]. Celli and Ghiani employed a multi-objective evolutionary method to size and position DG [58].

1.4 Organization Of Project

This project has been outlined in five chapters.

Chapter 1, Provide an introduction of distributed generation.

In chapter 2, A brief introduction is introduced to power loss methods for reducing losses in the distribution system and the theory of the proposed method.

Chapter 3, Provides a concise overview of the process of identifying the potential nodes for DGs location, the target function for system losses, and the DGs size selection using a Genetic Algorithm.

Chapter 4 Simulation Result and Discussion.

Chapter 5 Conclusion and furtuer work.

Chapter 2

Theoretical Background

2.1 Introduction

Losses in transmission and distribution account for the majority of system losses. This is a well-researched and old topic. However, as seen in [3] there is a lot of room for loss reduction in certain of emerging countries. In reality, system losses are divided into two categories: capacity or kW losses and energy or kWh losses, the latter of which might result in a higher monetary value at the end of the year [4]. Even if the losses cannot be eliminated, they can be reduced to a manageable level. According to studies, distribution networks account for 70% of total network losses, whereas transmission lines account for just 30% of total network losses [1]. The drive to improve total power delivery proficiency has compelled power companies to decrease losses, particularly at the distribution level. For reducing distribution network losses [1,2].

Losses reduction in power transmission networks will entail more efficient use of fossil fuels, resulting in lower emissions of air pollutants and greenhouse gases. Because a portion of the needed load current from upstream is generously reduced, DG coordination inside the distribution network minimizes power losses [5].

2.2 Losses In The Dns

As soon as electric power is created, it is transported over transmission lines to the many distribution circuits that are maintained by the utility company. This system aims to take electricity from the transmission system and provide it to customers in order to meet their requirements. However, throughout the distribution process, a large amount of the electricity generated by a utility is lost to losses. Transformers and distribution lines, are examples of tiny components in the distribution system that suffer from these losses [19].

When it comes to electricity distribution networks, there are two basic causes of loss. transformers and electricity lines .

2.2.1 Losses In Distribution Lines

When it comes to transmission and distribution system losses, one of the most important sources is the power lines that carry electricity from the substation to the loads. Copper losses account for almost all of the active power losses, which might be lost in the DNs. The losses in distribution lines are a function of the square of the current flowing through the line. Because copper losses in distribution lines may be assumed to account for all of the power loss in the lines, it is possible to compute it using Eq. 2.1.

$$p_{loss} = I^2 \times R \quad (2.1)$$

The degree of the active power losses in branches is dependent on the amount of current passing through the line and the resistance of the line. It is reactive power, which does not convey any energy, that is created at the point where current flows between any two buses.

In addition to the previously mentioned power losses, the reactive current flow in the line results in additional power losses. Because a part of the power from upstream has already been lowered because of DG integration, active power losses have already been minimized. It is possible to minimize losses even more by adjusting the voltage profiles that are present in the network. The traditional practice calls for the addition of capacitor banks to the distribution network in order to manage the flow of this reactive power. It is possible to switch in and out of these capacitor banks in order to supply reactive power in steps; however, this lowers the overall quality of the power given to the consumer due to the step variations in node-bar voltage.

Therefore, it can be concluded that anything which alters either current or line resistance will have an impact on the quantity of power lost via the line.

The quantity of active and reactive power loading at the end of the line is the most important component in determining the magnitude of line current. As the amount of electricity sent through the line rises, the amount of current flowing through the line also increases. Another element that influences the amount of current that flows through a line is the operating voltage of the line. A high voltage line will have a lower current than a low voltage line for a given amount of active and reactive power demand, denoted by apperent power S . As can be shown in Equation 2.2, this is true.

.

$$S_{line} = V_{line} \times I_{line} \quad (2.2)$$

As a result, the higher voltage line will have fewer copper losses.

A further aspect of increasing losses is imbalanced loads.

However, although the current level has the greatest impact on line loss, the resistance of the line cannot be overlooked. According to the inverse proportionality, resistance increases as the cross-sectional area decreases, whereas the length and resistivity increase in direct proportion. In Equation 2.3 below, R denotes resistance, ρ denotes resistivity, L denotes line length, A denotes an effective cross-sectional area, and R denotes resistance denotes resistivity

$$R = \rho \frac{L}{A} \quad (2.3)$$

Consequently, a long line with the same current flow will have higher losses and resistance. The same is true for conductor size, with a larger conductor resulting in lower resistance and lesser losses than a smaller conductor.

2.2.2 Methods For Reducing Losses In The Distribution System

Because distribution losses reduction account for a significant degrade portion of the utilities' profits, it is vital to investigate the different techniques for minimizing these losses. Even though there are several techniques for minimizing losses that may be utilized on existing systems, some approaches are more effective when employed during the installation of a new DN. As an illustration, consider the careful selection of the site of the substation in order to limit the length of distribution lines that will be required. Other methods include using the highest possible line voltage that is practicable in order to keep the current in the lines to the lowest value possible. Furthermore, since aluminum has a higher resistivity than copper, it will experience greater losses than a copper distribution line of equal size [27]. The use of shunt capacitor banks to reduce system losses is perhaps the most widely used means of doing so. It is necessary to utilize capacitors with a power factor that is close to unity.

As a result, fewer losses are obtained. The capacitors have been deliberately positioned in order to give the highest voltage support and current reduction possible. According to one example study, the usage of shunt capacitors was able to minimize distribution system losses by around 20%. When deciding where to locate the capacitor banks, however, extreme caution must be used. When the capacitors are evenly distributed throughout the system [19, 26].

Another technique for minimizing system losses is to reduce the number of harmonics that are present in the system, which may be done in many ways. This may be performed by installing filters at each load that generates significant non-sinusoidal signal output.

This research will be used for distributed generation, which is one way to reduce losses.

2.3 Forward/Backward Algorithm For Load Flow Application

A load flow is a computer simulation of the electric power system that estimates the quantity of electricity that will flow on each transmission line linking the producing facilities to the customers' homes and businesses [30]. A system's planner, designer, and the operator may all benefit from the load-flow solutions since they give essential information. The designer must be able to analyze design choices for complex systems in a timely and cost-effective manner. When using the load-flow software, designers may rapidly simulate the functioning of the system for a large number of design variants that are mutually incompatible with one another. The operator is concerned with the system's ability to operate reliably and efficiently as it now exists. The load-flow software is capable of predicting the losses associated with various system configurations that are accessible to the system operator.

For many decades, researchers have been studying how to make this software run as quickly, efficiently, and accurately as possible. The solution to the load-flow issue entails matching the characteristics of the source and the load using the current rules imposed by the transmission line to get the desired result. The output voltage of generation plants is controlled in order to maintain a consistent voltage. Consequently, power supplies are often treated as constant voltage sources in the load-flow program to account for this. There are many different techniques to simulate customer loads. The constant power load model is the most often seen load type. There are load flow methods that may be used to address large unbalanced and mutually connected radial distribution circuits that are not balanced. The Ladder Load-Flow Method is an example of such a method. Specifically, the Ladder Load-Flow Method has been extended to address looping systems, which is the fundamental contribution of this study.[30] When compared to algorithms created specifically for transmission analysis, the Ladder Load-Flow Method provides several benefits. Probably the most notable feature of the Ladder Method is that it can be written down without the need for matrix operations. For big systems, matrix operations cost a significant amount of time and memory. The connection of the system is represented by "points" in this version of the Ladder Load-Flow Method. Such an approach improves the speed of execution while also organically dealing with the sparsity of the system's data structure. This strategy will be used to solve the problem of the distribution network, among other things. The following are the most important aspects of this innovative approach [30] :

1. In order to minimize processing time and memory consumption, pointers are used extensively.
2. Online maintenance of attribute and topological data.

3. The representation of Devices that are regulated, such as the Tap Changer and Capacitor.
4. Run-on a personal computer's operating system.

2.3.1 The Ladder Load Flow Method

When using the Load-Flow algorithm, only the trace techniques are capable of providing "online" data attributes and topological data maintenance. Trace techniques are also well suited for representing controlled devices, as previously stated. The Y Bus matrix must be constructed in order for the other techniques to work. This matrix must be rebuilt if any changes are made to the attribute, topological, or control data. The Ladder Load-Flow method was chosen for the solution of distribution networks as a result of this consideration. The tracing technique used by the Ladder Load-Flow algorithm is called a trace method. Mutual coupling may be represented by the algorithm. It is competitive with other methods in terms of memory consumption as well as total processor time spent. With the help of the circuit shown in Figure 2.1, the fundamental ladder approach will be demonstrated.

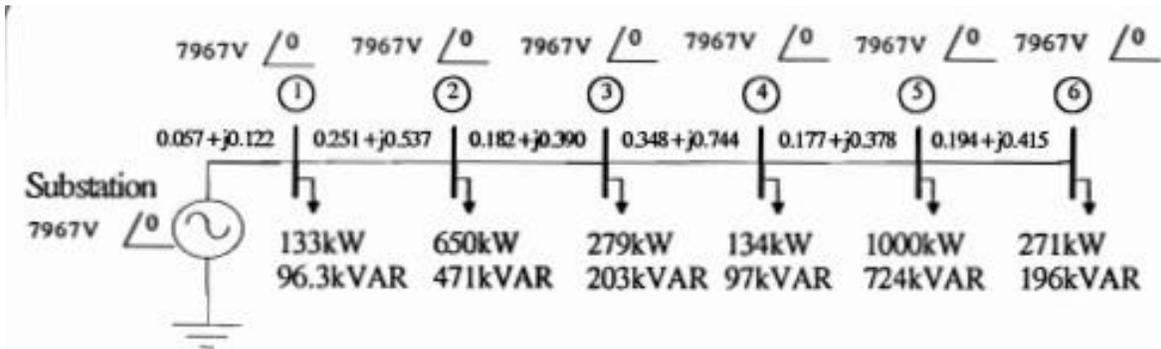


Fig 2.1 Illustrative Circuit For The Ladder Approach [36]

The magnitudes of bus voltages in volts, angles in degrees, line impedances in ohms, and bus loads in kilowatts and kilovars are depicted in Figure 2.1. To begin, the iterative algorithm estimates the voltage at each load bus. As indicated in Figure 2.1, the substation voltage may be utilized as a starting point. The resultant load currents may be calculated using these voltages as

$$I = (S/V)^* \quad (2.4)$$

As illustrated in Figure 2.2, after the load currents are obtained, the resultant line currents may be calculated. The product of the line current and line impedance may then be used to compute the voltage drop across each line. As a consequence, the voltage at each bus is recalculated, as illustrated in Figure 2.2. Iteratively repeat the technique until the bus voltages converge.

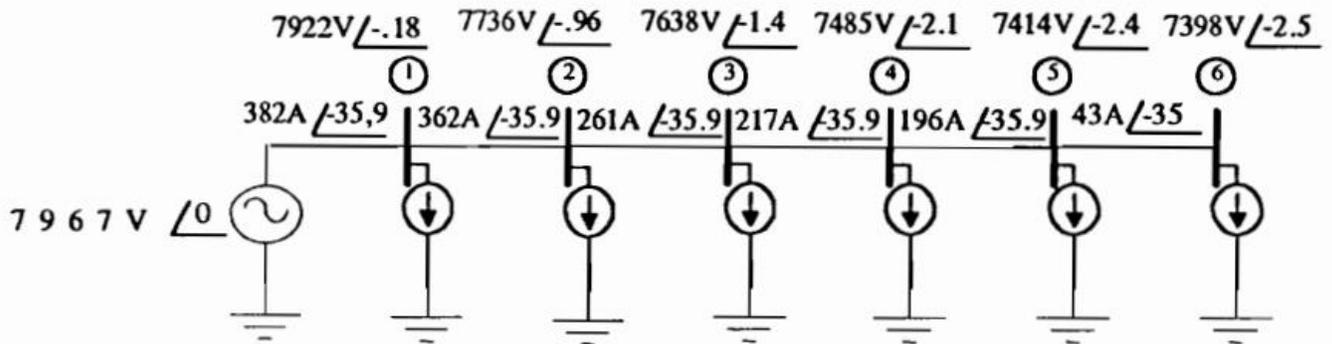


Fig 2.2 Currents For Ladder Method [36]

The ladder technique is based in principle on a circuit approach that was initially presented in 1967 [36]. To begin, the approach converts nonlinear kVA loads into linear load currents. As a consequence, a linear circuit is formed. After that, the linear circuit is solved, yielding fresh load current estimates. The approach is quite similar to the iterative Gauss-Seidel method for solving algebraic equations.

2.3.2 Load Flow Of Radial Distribution Networks

A feeder is a device that transports electricity from a source to loads. This planning strategy makes use of radial feeders that are either single or numerous. Generally speaking, it is possible to reduce overall power losses in DNs by reducing active power flow in lines (i.e., by meeting a portion of the load locally with local DG). When load flow is done, calculation the overall power loss of the network, as well as the maximum voltage variation is possible. In this instance, the Forward/Backward Sweep Load Flow method is used to move the load. Because it is possible to calculate the impedance of a feeder branch, the Backward sweep is the first stage in the Forward/Backward Sweep Load Flow technique, while the second step is the forward sweep.[36]

Backward sweep: When there are N nodes in the DN, the currents of load connected at each node are formulated as:

$$\bar{I}_L(M) = \left\{ \frac{p_L(m) - jQ(m)}{\bar{V}^*} \right\} \quad [m=1,2, 3, \dots, N] \quad (2.5)$$

where, $p_L(m)$ and $Q_L(M)$ represent the active and reactive of the load connected at node m and the overbar notation (\bar{X}) indicates the phasor quantities, such as \bar{I} and \bar{V}^* . Then, the branch current can be calculated as:

$$\bar{I}(mn) = \bar{I}_L(n) + \sum_{m \in \Gamma} \bar{I}(mn) \quad (2.6)$$

The set (Γ) consists of all nodes that lie beyond the node (n) [33].

Forward sweep: it is the next step to calculate the voltage at each node of a DN after the backward sweep in the manner described below:

$$\bar{V}(n) = \bar{V}(m) - \bar{I}(mn) Z(mn) \quad (2.7)$$

When a branch has an impedance of $Z(mn)$, the receiving and transmitting end nodes of the branch are represented by nodes n and m , respectively.

The following is a description of the complex load S_i of a node in a distribution system :

$$S_i = P_i + jQ_i \quad \text{where } i = 1.. 2...NB: \quad (2.8)$$

As a result, Equivalent current injection (ECI) may be represented as follows:

$$I_i = I_i^r(V_i) + jI_i^l(V_i) = \left(\frac{P_i + jQ_i}{V_i} \right)^* \quad (2.9)$$

To solve the load flow, the ECI of the i th node for the k th iteration is computed as follows:

$$I_i^K = I_i^r + jI_i^l = \left(\frac{P_i + jQ_i}{V_i^K} \right)^* \quad (2.10)$$

The flowchart of the forward/backward algorithm is illustrated in Figure 2.3

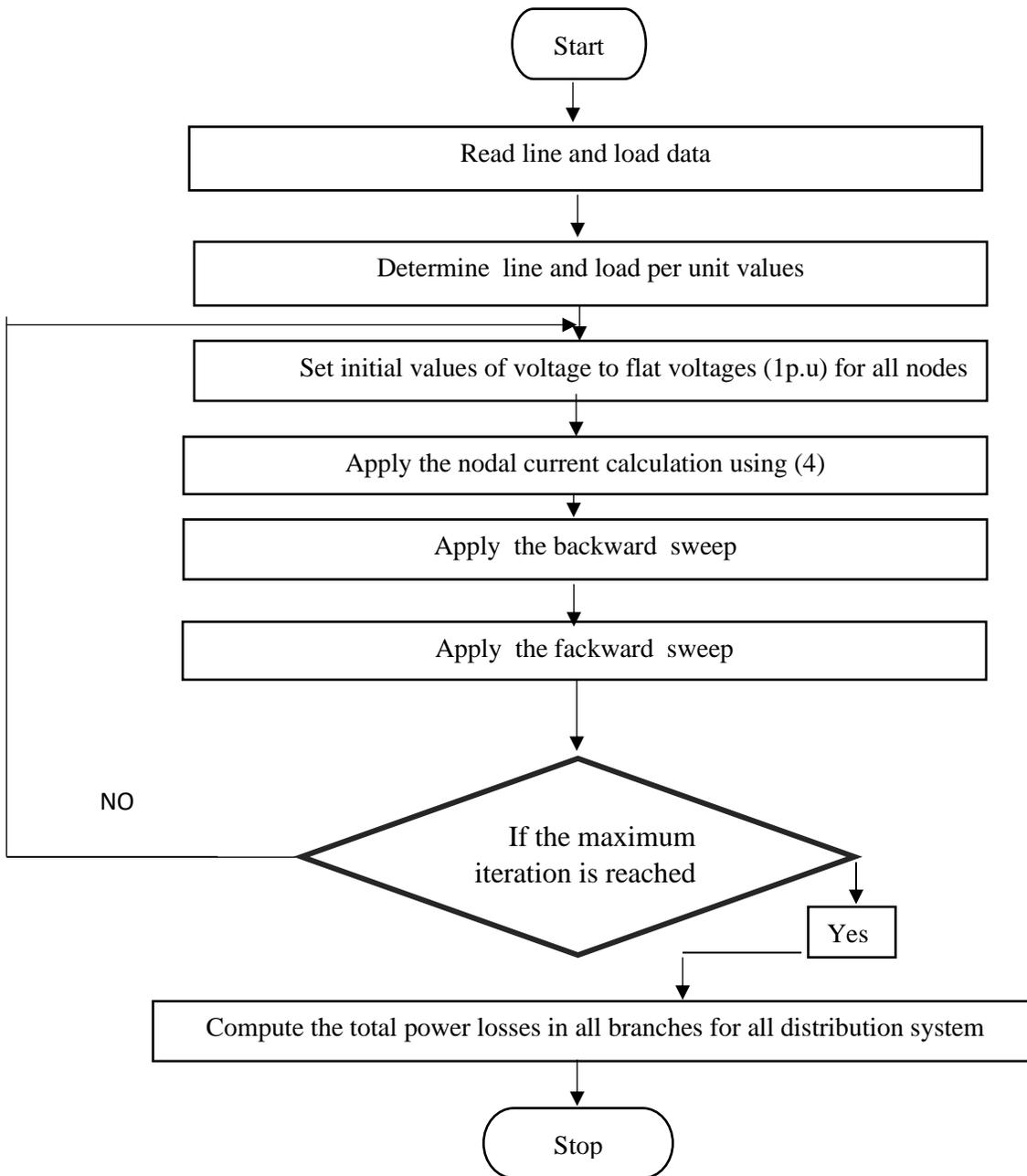


Fig 2.3 Flowchart For Ladder Load Flow

2.4 Distributed Generation

Distributed generation (DG) refers to small power producing units positioned near load centers, reducing the need to extend the network to serve additional load regions or maintain the increasing energy transfers required to meet consumer demand. There is no globally agreed definition of DG, with each organization providing a unique definition that, in essence, expresses the same notion. The International Energy Agency defines DG as a generating plant linked to the grid at the distribution-level voltage that serves a customer on-site or provides assistance to a distribution network [33]. At first look, distributed generation (DG) would seem to be the solution to many of the challenges facing today's distribution grids. In further detail, however, various concerns must be resolved, including the operational absorption into the grid and power market processes, as well as network and protection scheme adaptation, among other things. Furthermore, the sort of DG technology that has been used introduces additional limits and limitations.

2.4.1 DG Operation

The operation of DGs is dependent on several factors, smart technologies and operational modes among others. Either an electric utility or a consumer can own, operate, and control DGs deployed in the distribution network. If DG is claimed by a utility, its operating cycle is commonly known to be regulated by the utility. The motive for DG use in the distribution system determines the condition of the DG working cycle [6-7]. Consider the following scenario:

- A. Peak crest load shaving requires a limited number of operational time units (Internal combustion engines, small fuel cell units).

B. Power supply for the base load (Micro-turbines and large fuel cells)
Environmental factors, like wind speed and sunshine, have an impact on renewable energy units (Wind generators and solar cells).

Customer-owned DG operating cycles, on the other hand, are unknown to the operators unless the electric utility and the customer have signed a unit commitment agreement, which is unlikely. Small customer-owned DG operating cycles are thus recognized as erratic operations from the electric utility's standpoint. The utility has no say over how it operates.

2.4.2 DG Siting

The restrictions on where DG units can be placed in the distribution system is the open equation due to geological constraints imposed by substations. If the DG is owned by the customer, the utility does not influence its position because it is installed at the customer's premises. The location of the DG is determined by a few considerations, for example:

- Supplying the needed additional load requirement.
- Reducing the system losses.
- The voltage profile improvement.
- Not interfere with current protective device coordination and ratings when DGs are injected.

2.4.3 DG Size

Deciding the quantity of DG units to add to the network is not easy. However, there are a few factors that might influence the size of the DG unit:

- A. It is sufficient to use DG units to improve overall system performance [3]. To lessen the substation burden, greater DG capacity might be used [6-7].
- B. If there is an incidence of islanding, the DG size must be more than double the needed island load for reliability reasons.[16]
- C. As a result, the protective system settings must be readjusted and/or rebuilt as the DG size grows [1-2].

2.5 GENETIC ALGORITHM

Generalized Genetic Algorithms (GAs) are a kind of exploratory search method that is based on the evolutionary concepts of characteristic selection. A genetic algorithm is a heuristically guided random search approach that assesses thousands of posited solutions at the same time using heuristics. To proceed toward better solutions, biased random selection and mixing of the assessed searches are carried out after this first step. It is based on the functioning of genetic DNA that the coding and manipulation of search data take place, and the selection process is taken from Darwin's theory of survival of the fittest. Search data is often encoded as binary strings known as chromosomes, which are then grouped to create populations. Typically, mixing entails recombining the information contained in two chromosomes that have been randomly picked from the whole population to create a new set of data. I. Rechenberg published "Evolution strategies" in the 1960s, which was the first publication to describe evolutionary computing. Other researchers built

on his initial concept and refined it. Genetic Algorithms (GAs) were developed by John Holland at the University of Michigan and were the first of their kind [16]. Figure 2.4 depicts the procedure of using a genetic algorithm.

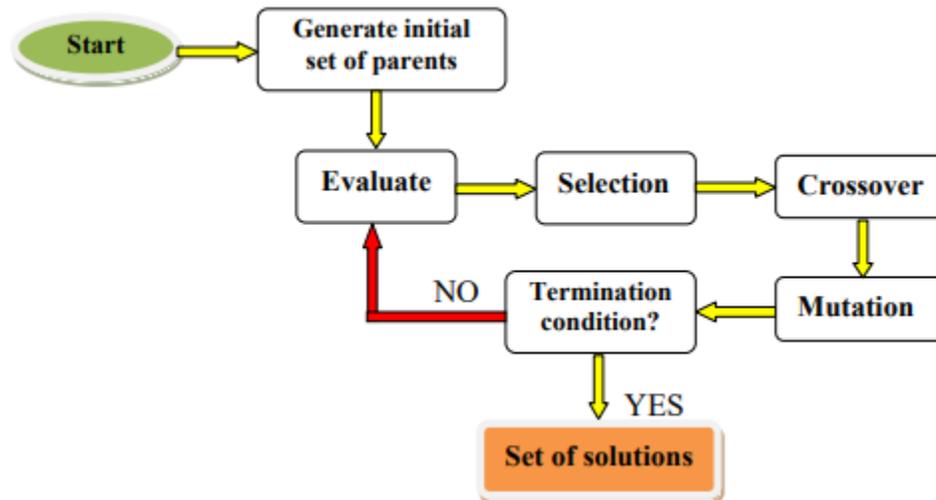


Fig 2.4 Genetic Algorithm Process.

2.5.1 The Description Of GA

The algorithm starts with a collection of solutions (represented by chromosomes), which is referred to as the population. Each population is used for the formation of a new one. A desire to ensure that the new population would be superior to the previous one motivates this decision [14]. The solutions that are subsequently picked to find new solutions called offspring are selected based on their fitness - the more appropriate they are, the greater the likelihood that they will be selected to reproduce. A similar pattern is continued until a certain condition is met. In computing, search space is defined as the set of all possible solutions. The search space represents all potential solutions to the problem at hand. Depending on the value (or fitness) of a solution for the issue, each viable answer may be "marked." By using GA, we can

find the optimal answer out of a large number of viable choices. The difficulty is that the search process might be quite time-consuming. It is possible that one does not know where to seek a solution or where to begin. When looking for a good solution, several techniques may be used, but not all of these approaches are necessarily the most effective [16].

A basic genetic algorithm that produces satisfactory results in a wide range of practical issues is built on three operators:

- I. **Reproduction:** In this operator, string animals are subjected to a fake form of natural selection based on Darwinian survival of the fittest principles. A variety of different algorithms may be used to implement the reproduction operator in algorithmic form. Figure 2.5 shows the random selection of parents.

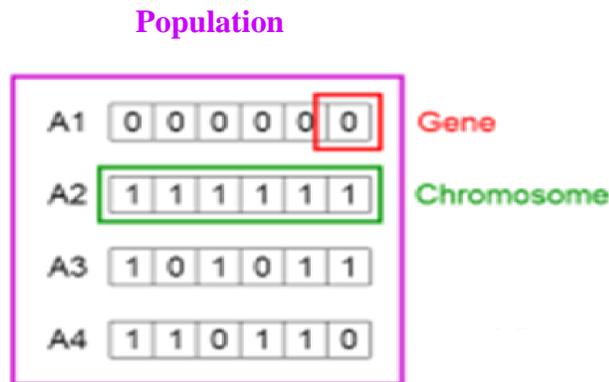


Fig 2.5 Random Selection

- II. **Crossover:** It happens after the process of reproduction or selection. It aims to generate two new populations or strings from two existing ones recombining randomly selected parts created by a randomly chosen crossover point, and it does so by genetically recombining randomly chosen parts formed by a randomly chosen crossover point.

2.5.2 Type of crossover

2.5.2.1 One-Point Crossover:

One-point crossover is perhaps one of the simplest and most fundamental crossover operators there is, as well as one of the most basic crossover operators. When using this approach, a cut point is chosen at random. Then, by following the processes outlined below, the parent chromosomes can produce offspring. Figure 2 depicts two parent chromosomes for the sake of illustration and comprehension. As shown in Fig 2.6, the cut point was chosen at random. When a chromosome/offspring is suffixed with the initial node, the sequence of nodes on that chromosome/offspring indicates the path taken by the vehicle.

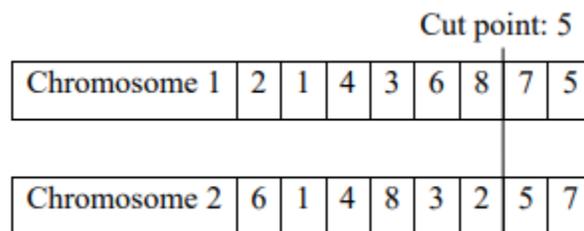


Fig 2.6 Parent Chromosomes.

Each of the cut points has an equal probability of being reached. According to [12,15] the first parent will give the gene for the new child to the cut point and non-repeating genes from the beginning of their second parent.

- i. As illustrated in Fig.2.7, choose a cut point at random between any two genes (for the sake of simplicity, the cut point is referred to as an empty rectangular box throughout this study). As a result, two substrings are formed in each of the parent chromosomes, one before and one after the cut point.
- ii. Parent 1 give and paste it into the Offspring 1 exactly as it is.
- iii. Copy each gene from the Parent 2 one at a time and put them one at a time into the Offspring 1, deleting the repeated values to prevent duplication.
- iv. To produce offspring 2, the roles of the parents are switched around.

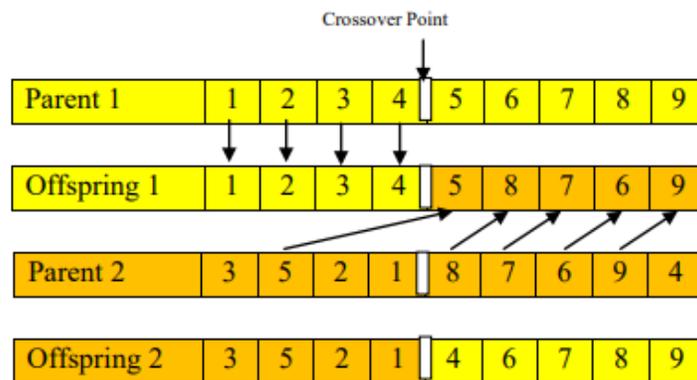


Fig 2.7 One-Point Crossover Is Depicted As A Diagram.

2.2.5.2 Two-Point Crossover:

The concept is exactly similar to one-point crossover. The two cut points are chosen at random at the same places in two parents, and two offspring are produced from them.

- I. Choose cutting points (let's say two cutting points) between the genes of each parent at random from the list.
- II. Figure 2.8 shows how to choose the substring.
- III. The remaining from the first parent are inserted exactly as they are in Offspring 1, except for any repeated values. For example, in Fig.2.8, genes 1 and 8 have already been inserted in the center of the Offspring 1 population. As a result, they are excluded by being copied to it.)

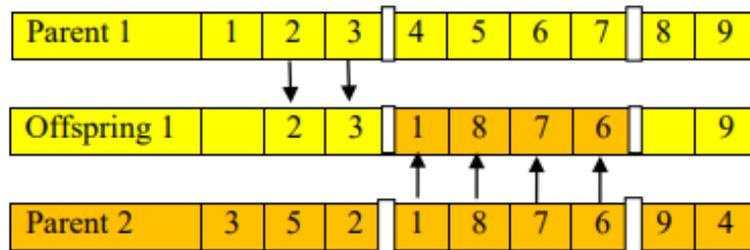


Fig 2.8 Two-Point Crossover Is Depicted As A Diagram.

- IV. Offspring 1 is filled with the genes that did not appear in the first parent and substituted with genes that appear in the second parent after the second cut point of it, as depicted in Fig.2.9.
- V. Offspring 2 may be formed similarly by swapping the roles of the parents, as illustrated in Fig.2.10, which is represented as Offspring 2.

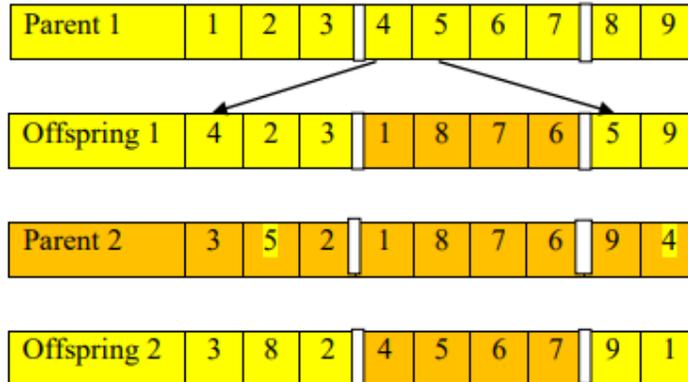


Fig 2.9 Two-Point Crossover Is Depicted As A Diagram.

III. Mutation: It is the occurrence of a random change in the value of a string position regularly. The mutation is the process of creating a new string by modifying the value of an existing string as shown in figure 2.10.

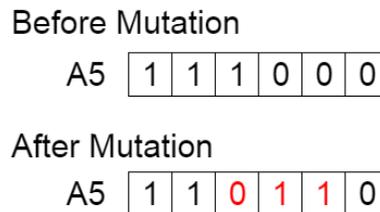


Fig 2.10 Mutation

IV. Fitness function: There are two components to defining a standard genetic algorithm: (1) solutions, and (2) a fitness function to assess those representations. The fitness function is constantly dependent on the task at hand. Once the genetic representation and fitness function have been determined, GA continues to randomize the initialization of a population of solutions, then improves the population via the application of mutation, crossover, and selection operators on a repeated basis.

2.5.3 Parameters Of GA

GA is defined by two fundamental parameters: the crossing and the mutation probability. Other considerations include the size of the population, among other things.

Crossover probability is the frequency at which crossover will be done. If there is no crossover between parents and children, the kids are identical copies of their parents. Whenever there is cross-pollination, children are created from chromosomal segments from both parents. If the likelihood of crossover is one hundred percent, then all offspring are produced through the crossover. When chromosomes are crossed, the aim is that the new chromosomes will have beneficial elements of the old chromosomes and that the new chromosomes would be better as a result [16].

Mutation probability is the frequency with which different regions of a chromosome will be altered. If there is no mutation, the offspring are produced immediately after the crossing (or are directly replicated) without any modification. When a mutation is carried out, one or more sections of a chromosome are altered in some way. If the mutation probability is 100 percent, the whole chromosome is modified; if the mutation probability is 0 percent, nothing is altered. In most cases, mutation prevents the GA from reaching extremes in a particular region. It is important that mutations do not occur often, since else GA will revert to random search [16]

Population size is the number of chromosomes present in a population (in one generation). GA has few opportunities to execute crossover when there are too few chromosomes, and only a limited portion of the search area is examined if there are too few chromosomes. GA, on the other hand, is slowed down if there are too many chromosomes present.

2.5.4 Algorithm Of Basic GA

Multiobjective GA is used for DG placements in a radial distribution, which is the approach that has been proposed.[17]

- Step1: Prepare the line, load the data into it, and then deliver it to the user as an input parameter.
- Step2: Calculate the flow of the load and decide the delivery method.
- Step3: Create a random starting population and set the iteration count to zero before continuing.
- Step4: Find out what the DG's maximum size and location are (no. of a bus).
- Step5: If the bus voltage does not fall within the chromosome's authorized range, the chromosome is deemed infeasible and should be removed from the experiment.
- Step6: Figure out the value of the fitness function for each chromosome in this condition, which corresponds to the value of the objective function F . (5).
- Step7: Sort the objective function values from lowest to highest, discarding the values that are not fit and preserving the values that are the fittest.
- Step8: To generate a new set of chromosomes, utilize the preserved chromosome to carry out Mutation and Mating procedures on the other chromosomes.
- Step9: To find out how to fit each of the newly generated chromosomes, use the fitness values.
- Step10: Increase the number of iterations by one and repeat steps 5 through 9 as many times as necessary until the number of iterations reaches the maximum.

2.6 SUMMARY

This chapter aims to provide a basic definition of distributed power generation in competitive energy markets by discussing the pertinent concerns. There is also a discussion of the phrases distributed resources, distributed capacity, and distributed utility.

CHAPTER 3

Proposed Method

3.1 Introduction

The purpose of this research seeks to increase system loss reduction and enhance the system voltages by determining the best DG position and size in a particular DN by using a genetic algorithm and loss sensitivity factor..

3.2 DG Location

The Loss Sensitivity Factor (LSF) is utilized to determine sensitive buses to connect DG. And then, the LSF is ordered in ascending order which in turn helps to reduce the search space and processor time during the optimization process. The bus with the highest value of LSF will be the first candidate bus for the DG injection. The single line diagram of two buses is shown in Fig. 3.1. The $P_{loss(i,j)}$ and $Q_{loss(i,j)}$ can be determined using (3.1) and (3.2), respectively.

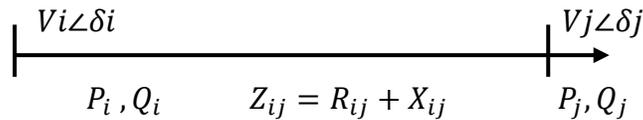


Fig 3.1 Single Line Diagram Of Two Buses

$$P_{loss} = \frac{P_j^2 + Q_j^2}{|V_j|^2} R_{i,j} \quad (3.1)$$

$$Q_{loss} = \frac{P_j^2 + Q_j^2}{|V_j|^2} X_{i,j} \quad (3.2)$$

the first derivative of $P_{loss}(i,j)$ and $Q_{loss}(i,j)$ with respect to P_j which results in the equations (3.3) and (3.4).

$$\frac{\partial P_{loss}(i,j)}{\partial P_j} = \frac{2*P_j*R_{i,j}}{|V_j|^2} \quad (3.3)$$

$$\frac{\partial Q_{loss}(i,j)}{\partial P_j} = \frac{2*P_j*X_{i,j}}{|V_j|^2} \quad (3.4)$$

The LSF can be determined by taking absolute value of S_{loss} with respect to P_j as expressed in (3.5)

$$LSF = \left| \frac{\partial S_{loss}}{\partial P_j} \right| = \left| \frac{\partial P_{loss}(i,j)}{\partial P_j} + j \frac{\partial Q_{loss}(i,j)}{\partial P_j} \right| = \left| \frac{2*P_j*R_{i,j}}{|V_j|^2} + j \frac{2*P_j*X_{i,j}}{|V_j|^2} \right| \quad (3.5)$$

3.3 Objective Function

The optimal DG problem is aimed to minimize the power loss (P_{Loss}) in the DN, while all constraints of the power system and DG should be within limits. The objective function (OF) can be formulated as:

$$OF = \min \sum_1^n P_{Loss} \quad (3.6)$$

$$P_{Loss} = \sum_{i=1}^m \sum_{j=1}^n I_{ij}^2 R_{ij} \quad (3.7)$$

Where I_{ij} is the current between bus i and j, R_{ij} is the resistance between bus i and j, n and m are the total numbers of branches.

3.4 Networks Constraints

The network constraints can be divided as follows:

3.4.1 Equality Constraint

The active and reactive power flow equations as shown in (3.8) and (3.9) are used to enforce the equality constraints [29]:

$$P_G + P_{DG} = P_D + P_{LOSS} \quad (3.8)$$

$$Q_G + Q_{DG} = Q_D + Q_{LOSS} \quad (3.9)$$

Where P_G and Q_G are the source power, DG powers are denoted by P_{DG} and Q_{DG} , respectively. The entire load powers are represented by the variables P_D and Q_D . The power losses are represented by variables P_{LOSS} and Q_{LOSS} , respectively.

3.4.2 Inequality Constraints

According to the following equation, the voltage limits are shown in inequality constraints

$$V_{min} \leq |V_i| \leq V_{max} \quad i = 1, \dots, N_b \quad (3.10)$$

Where V_{min} and V_{max} are the minimum and maximum specified voltages at each bus, respectively, and for 69-bus systems, V_{min} and V_{max} are taken as 0.95 and 1.05 at each bus, respectively.

In the case of voltage division (VD), the following equation may be used to represent the limits:

$$|1 - V_i| \leq VD_{max} \quad i = 1, \dots, N_b \quad (3.11)$$

Where VD_{max} is the voltage division allowable in the DN.

The feeder must be able to withstand line capacity limit, which may be calculated as follows:

$$|S_{ij}| \leq |S_{max}| \quad (3.12)$$

Where S_{ij} indicates the apparent power in a branch connected to the node i and j and S_{max} is used to express the maximum apparent power at the branch (i, j) .

The DG units that are employed must be within the permitted size range, which is as follows:

$$P_{DG,min} \leq P_{DG,i} \leq P_{DG,max} \quad i = 1, \dots, N_{DG} \quad (3.13)$$

$$Q_{DG,min} \leq Q_{DG,i} \leq Q_{DG,max} \quad i = 1, \dots, N_{DG} \quad (3.14)$$

Where $P_{DG,min}$ and $Q_{DG,min}$ minimum DG output limits at bus i , respectively; $P_{DG,max}$ and $Q_{DG,max}$ are maximum output limits of the DG; $P_{DG,i}$ and $Q_{DG,i}$ represent the DG's capability to inject power; and N_{DG} represents total number of DGs.

The location of the distribution generator (DG) limits is:

$$2 \leq DG_{position} \leq N_b \quad (3.15)$$

3.5 The Proposed GA

The following is a detailed discussion of the proposed GA for the DG sizing Problem:

3.5.1 Initialization

Initialization is the process of creating a new population randomly. In this work, there are two optimization factors (i.e., rating/settings as well as the number of DG) included in the initial population, which are produced at random. The resulting value for each choice variable is determined using a random number generator. In addition to the substation bus, DGs of various sizes (kW ratings) have to be installed at each load node except for the substation bus. The algorithm's efficiency and performance are affected by the population size, generation size, crossover probability, and mutation probability, among other factors.

Two choice factors were taken into consideration for DG optimization in this research, below:

1. It specifies the network node numbers to which the DG is to be attached or installed, which is determined using the LSF.
2. Power size for the corresponding DG.

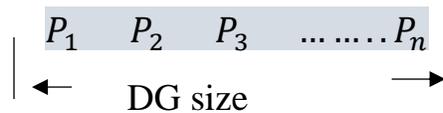


Fig. 3.2 Power Size Of Dg

3.5.2 Fitness Function

The goal function of this project is to find the DG placement and size to reduce system loss to the lowest possible value and improve the voltage to the highest possible within the constraints no more than 1.05 p.u.

3.5.3 Reproduction

Reproduction is the first genetic algorithm operator that may be used. This selects which chromosomes of the present population will be included in the mating pool that will be used to generate the future generation of humans and other animals. As a result, this operator is referred to as the selection operator for breeding in general. This is accomplished via the use of a skewed random selection strategy. The parents are therefore picked at random or from the present population in such a manner that the 'best' strings in the population have a greater probability of being selected. Alternatively, parents may be chosen from a pool of candidates. Several approaches may be used in this selection process, in this study, a random selection process was applied. A reproduction operator transferred an ancient chromosome into mating pool and used it as breeding stock. In the following generation, chromosomes with higher fitness values have a greater chance of being chosen into a mating pool and generating one or maybe more offspring than those with lower fitness values. A pair of mating chromosomes may produce two children from a single pair of chromosomes.

3.5.4 Crossover

Fig. 3.3 shows parents. One-point crossover used in this project, which is determined by generating a random integer between 0 and 1 and assigning the same priority (0.5) to both of the parent strings. Both of the parents are shown in distinct colors to aid in comprehending the situation.

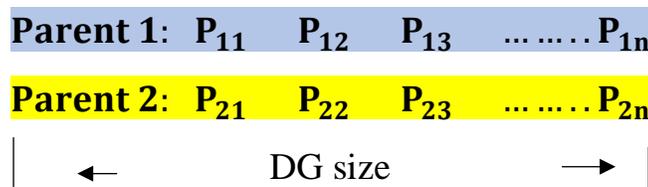


Fig. 3.3 Parents

Then, as seen in Fig. 3.4, offsprings are created.

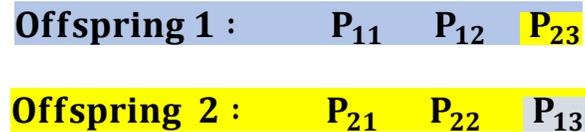


Fig. 3.4 Offsprings

It can be seen that each crossing led to the birth of the offspring. To adjust the rate of crossover, there is also a parameter defined as "Crossover Probability," which will be discussed in further depth later on. To complete the crossover procedure, this probability is employed as a decision variable. The crossover rate is the chance of a certain event occurring. The probability of a crossover occurs in the range of 0 to 1. To accomplish crossover, the following stages must be completed:

- step1. By using a random selection process, you may create a matting pool of parents' chromosomes. The size of the matting pool should be the same as the size of the population.
- step2. Choose one of the parent's pairs from the matting pool and produce a random number between 0 and 1 using the selected parent.
- step3. Set the crossover probability ' Ω_c '
- step4. In this case, if the random number is greater than the crossover probability " Ω_c " "There won't be a cross over and the offspring will only have one parent chromosome.
- step5. the randomly generated number is smaller than the crossover probability " Ω_c " then crossover occurs, and a single child is produced as a result of the crossover.

3.5.5 Mutation

Mutation creates new genetic material to preserve population variety. Random chromosomal variable or optimize variable modification (i.e. sizes). The mutation is shown below. Let the Mutation site be in the third place.

Chromosome before mutation

Parent 1: P₁₁ P₁₂ P₁₃

Chromosome after mutation

Parent 1: P₁₁ P₁₂ P_{xx}

Fig. 3.5 Chromosome Before And After Mutation

3.6 The proposed DG Allocation

The following are the measures that need to be taken in order to solve the DGs allocation problem:

- step1: To define the distribution network parameters, read the DN line and bus data.
- step2: Run the load flow and record the total power loss and all node voltages.
- step3: Calculate the LSF based on load flow results and sort the LSF in ascending order.
- step4: Select locations based on the LSF, where three locations were selected (61, 64, 65)
- step5: Set GEN = 0.
- step6: Create the initial population at random. Where the chromosomes only reflect the value of DG size.
- step7: Apply both load-data and bus-data (i.e. DG size) to the network matrices in accordance with their respective places.

step8: For each chromosome, carry out the load flow for distribution networks using the most recent system information. Calculate the overall power loss and voltage limits for each bus.

step9: Calculate the objective function of each chromosome in the population matrix and check the operational constraints.

step10: Introduce the best chromosome and save the population.

step11: $GEN = GEN + 1$.

step12: Using a random selection technique, create the individual pool from the original population.

step13: Do Crossover each chromosomal pair.

step14: Do mutations

step15: Set of children and calculate the DG size for every chromosome.

step16: Determine the objective function of every offspring.

step17: Introduce the best chromosome and choose the optimal chromosome from the present population and its descendants. Replace the original population with the best population available and utilize it for the following generation.

step18: Continue through step 9 until the solution converges.

step19: Stop.

The proposed optimization method for the DG issue is shown in Fig. 3.6 as a flowchart.

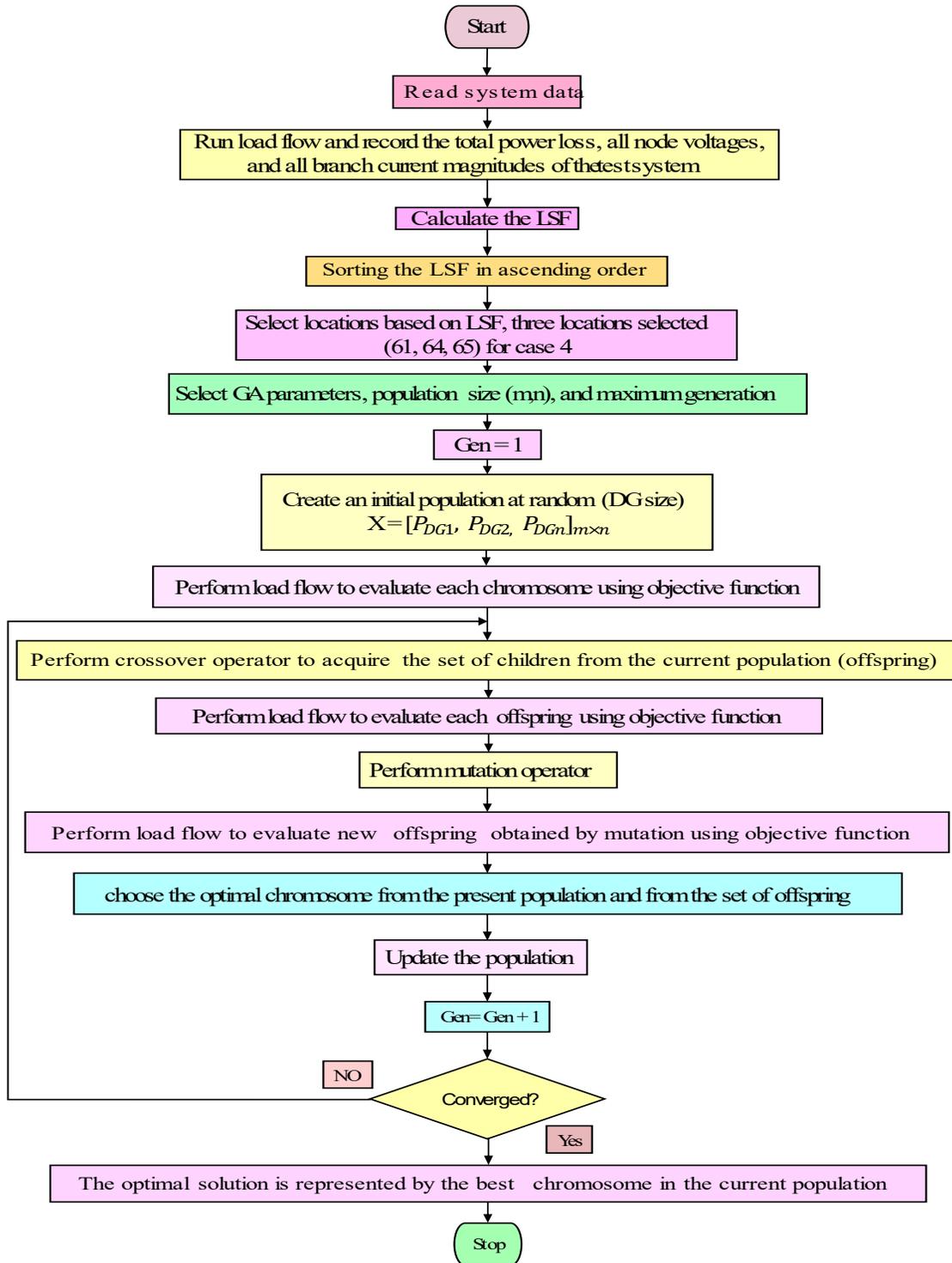


Fig. 3.6 Flowchart Of The Proposed Approach

Chapter 4

Simulation Result and Discussion

4.1 case of study

The IEEE 69__bus distribution test system was used to evaluate the performance of the suggested algorithms in terms of handling the DG allocation and size issue. All methods for this challenge have been designed in "MATLAB 2020. The system consists of 69 buses. Data of the network is obtained from [16]. Active power losses are 225 kW.

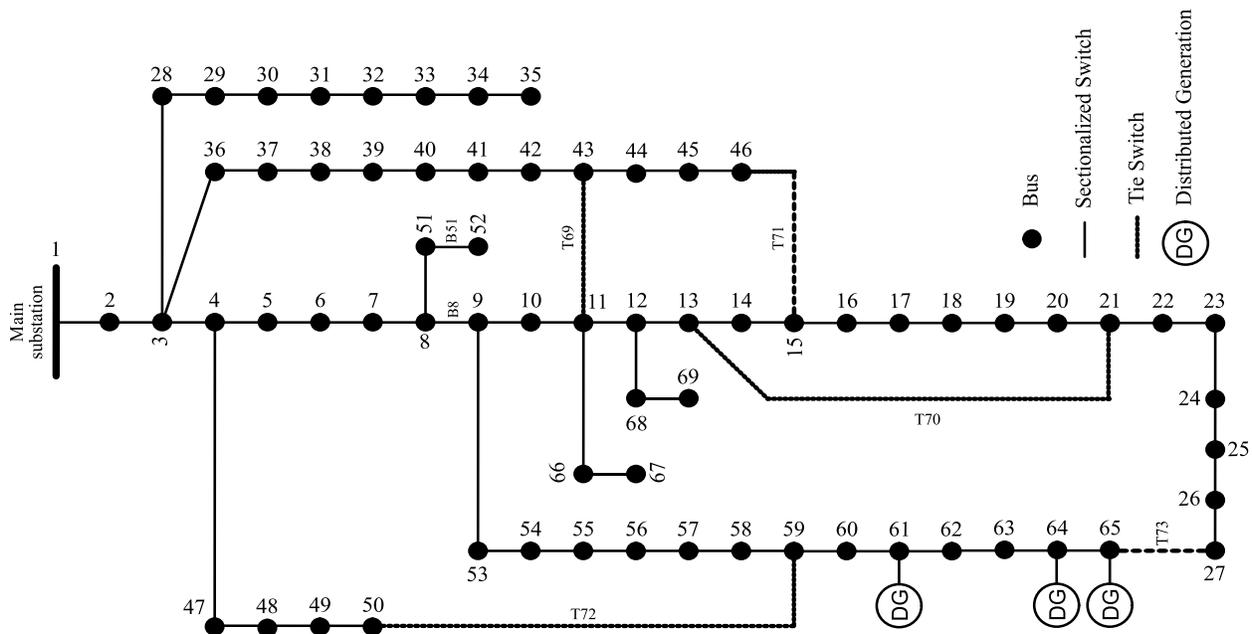


Fig. 4.1 IEEE 69-Bus With Candidate Dgs.

In most studies that have adopted the DG size and position problem, a possible solution has a two-component vector as shown in Fig. 4.2 for the challenge of determining the appropriate position and size of one DG unit.

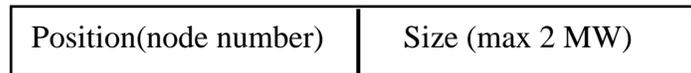


Fig. 4.2 Chromosome With Two-Component Vector

First, the location, or node at which the DG should be linked, is represented by bus numbers. The size of the DG represents the second part of the vector and may be ranged from 0 to 2 MW.

In this work, the location of DGs is determined using the LSF which means the chromosome has a one-component vector (i.e., the DG size).

In addition to the basic case, four different kinds of cases are considered in the project work.

1- Basic case

At the base case, the system has a power loss of 225 kW. The voltage profile, the current in the system branches, and the loss in the system branch are noticed below.

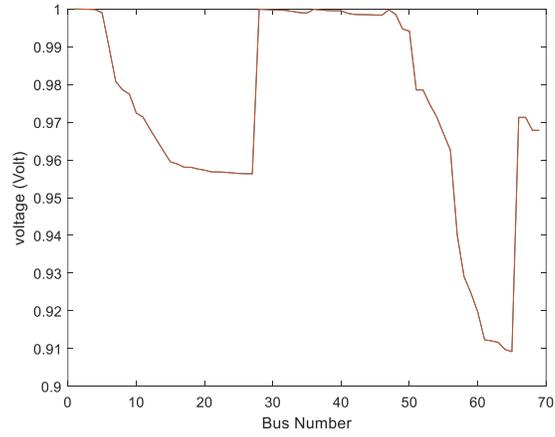


Fig. 4.3 Voltage Profile

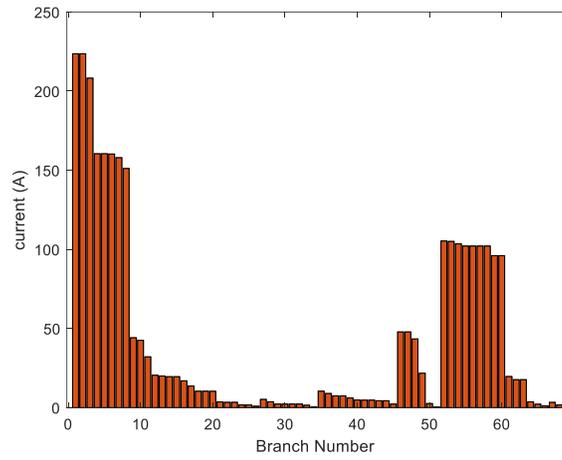


Fig. 4.4 Current In The Branch

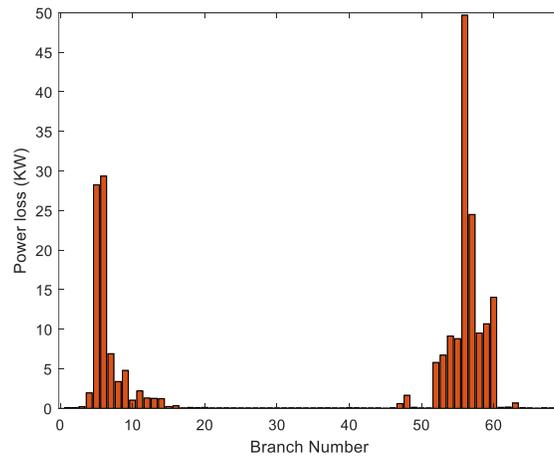


Fig. 4.5 Ploss In The System Branches

2- Case 1 Random Location And Size (Without Using GA)

This case is divided as follows:

A . Random Location And Size

In this case, the locations and sizes of three DGs were selected randomly, where three different locations from 2 to 68 and values for sizes from 0 to 2 MW were selected.

The DG locations and sizes are [50, 41, 30] and [1826.8 1264.7 195] kW. From table 1 the total loss of the network increased from 220 kW to 234.5 kW and the minimum and maximum voltage are equal to 0.9096 p.u and 1.0139 p.u, respectively, after the installation of DG units. The voltage profile, the current in the system branches, and the loss in the system branch are shown in Fig 4.6, 4.7, and 4.8.

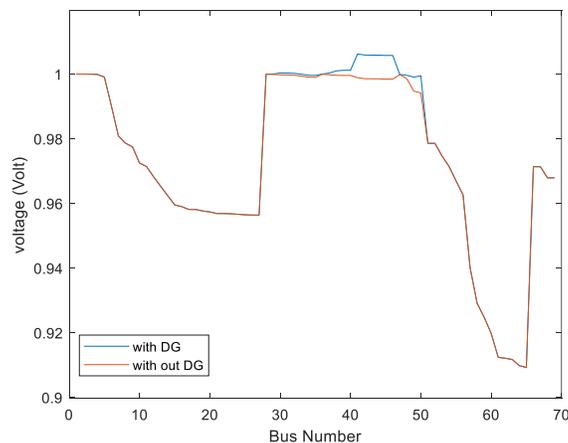


Fig 4.6 Voltage Profile

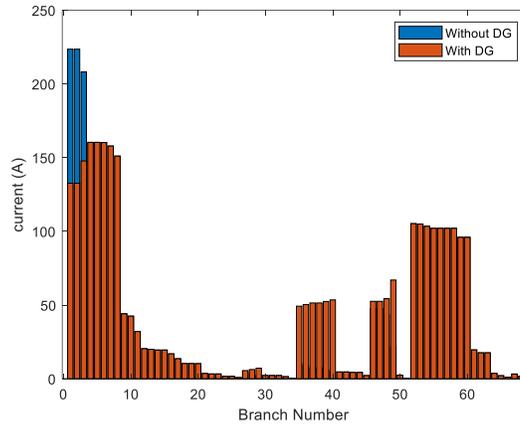


Fig 4.7 Current In The Branches

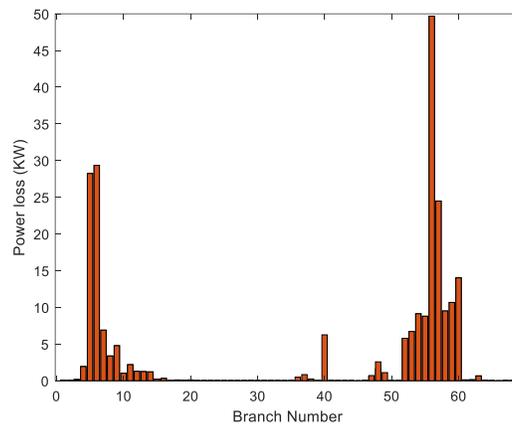


Fig 4.8 Ploss In The System Branches

B. Random Location And Size

In this case, also, the locations and sizes were chosen randomly, but only two locations and two sizes were chosen [20,39] and [1264.9,195.1] kW. From fig 4.11, it can be noticed that a small reduction in the value of power losses, which is from 225 KW to 207.6 KW and a slight improvement in voltage profile in terms of the minimum voltage, which is equal to 0.91726 p.u. The voltage profile, the current in the system branches, and the loss in the system branch are in Fig 4.9, 4.10, and 4.11.

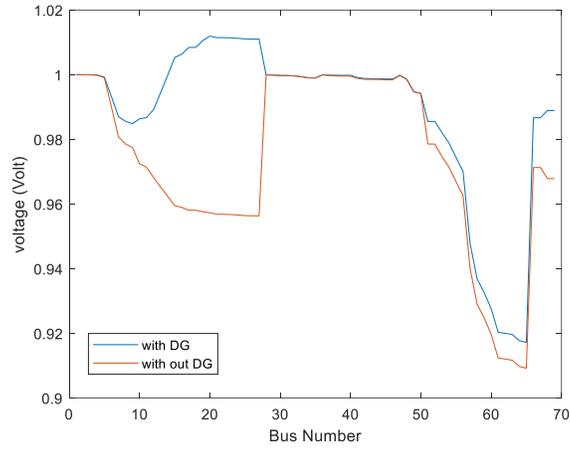


Fig 4.9 Voltage Profile

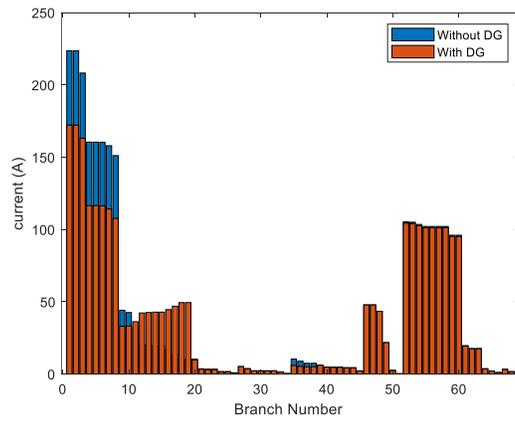


Fig4.10 Current In The Branches

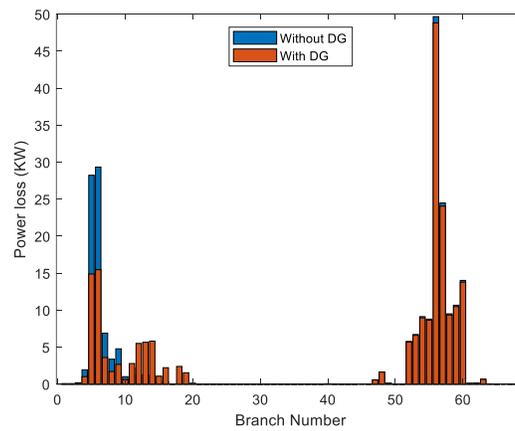


Fig 4.11 Ploss In The System Branches

C. Random Location And Size

In this case, one location and one size were chosen randomly [58] and [1500]. From table1 we notice the active power loss is minimized to 195.6 kW and the minimum voltage is enhanced to 0.9187 p.u. The voltage profile, the current in the system branches, and the loss in the system branch are shown in Fig 4.12, 4.13, and 4.14.

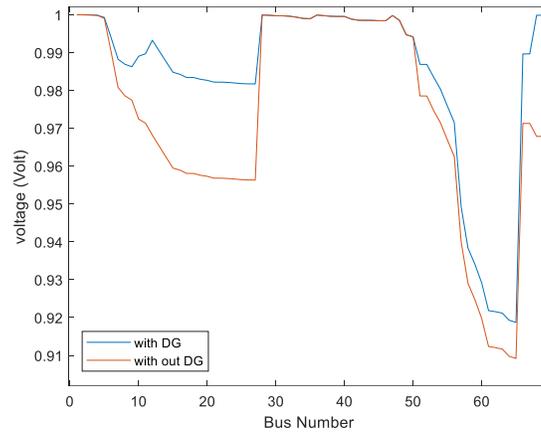


Fig 4.12 Voltage Profile

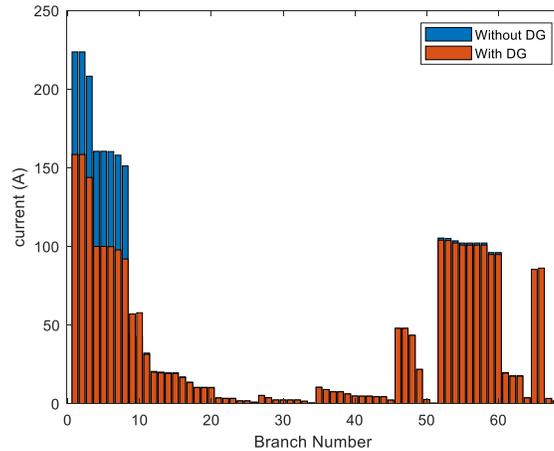


Fig 4.13 Current In The Branches

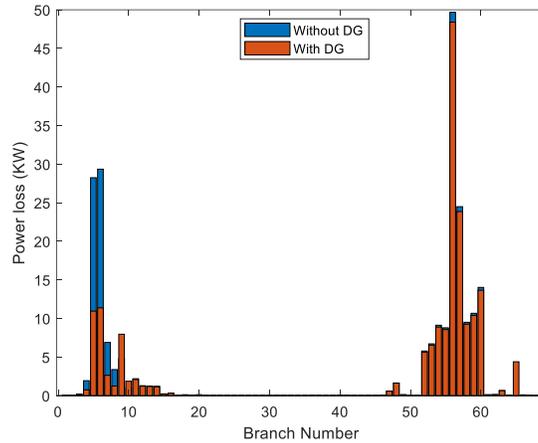


Fig 4.14 Ploss In The System Branches

3-Case 2 Random Size And Location Selected Using LSF (Without Using GA)

This case is divided as follows:

A. Random Size And Location Selected Using LSF

In this case, three locations were chosen based on LSF [61,64,65] and three sizes were randomly chosen from 0 to 2 MW [1941.2 1914.3 970.8]. It's the worst case in terms of power losses, as the value of loss reached 371.7 kW. As well as, the voltage profile is improved, but it exceeded the upper voltage limit (i.e., the maximum voltage is 1.05 p.u). The voltage profile, the current in the system branches, and the loss in the system branch in Fig 4.15, 4.16, and 4.17.

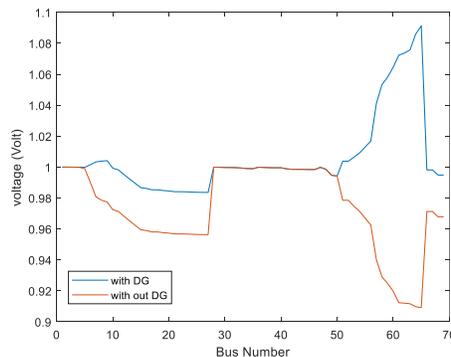


Fig 4.15 Voltage Profile

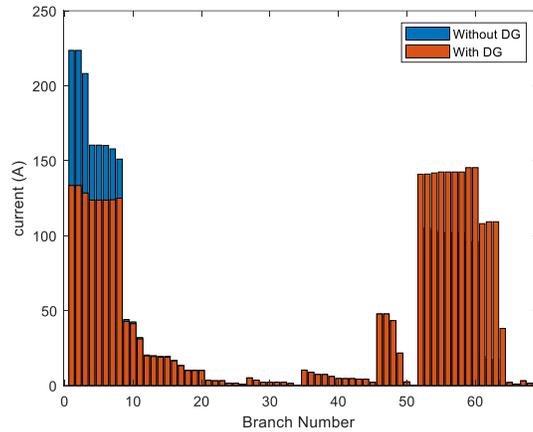


Fig 4.16 Current In The Branches

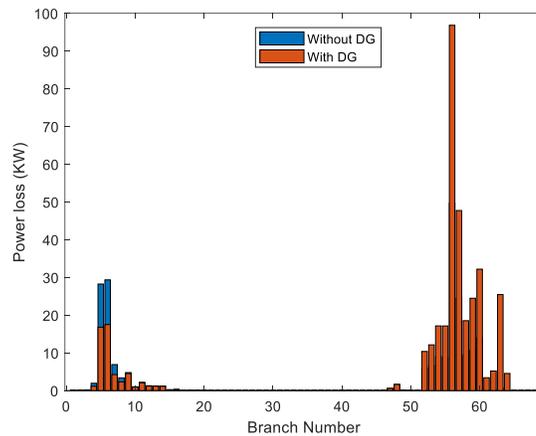


Fig 4.17 Ploss In The System Branches

B. Random Size And Location Selected Using LSF

In this case, just two locations were chosen based on LSF [61,64] and two sizes randomly chosen [1300 1100] kW. The minimum voltage was enhanced to 0.9713 p.u and active power loss was minimized to 96 KW. The voltage profile, the current in the system branches, and the loss in the system branch in Fig 4.18, 4.19, and 4.20.

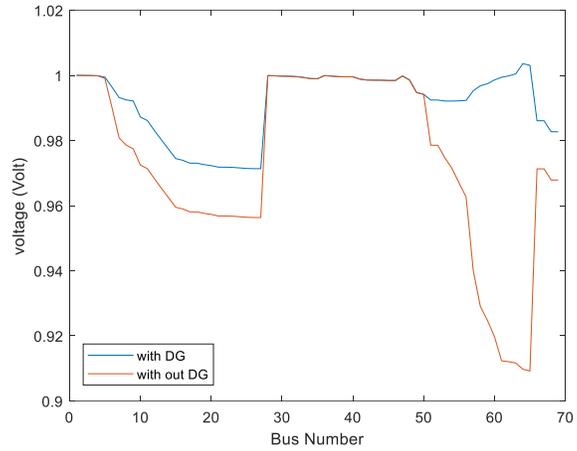


Fig 4.18 Voltage Profile

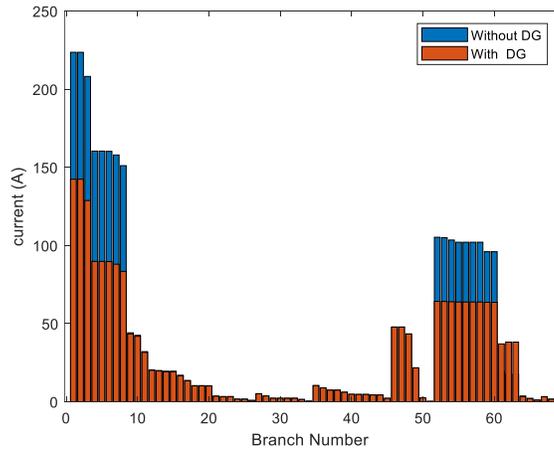


Fig 4.19 Current In The Branches

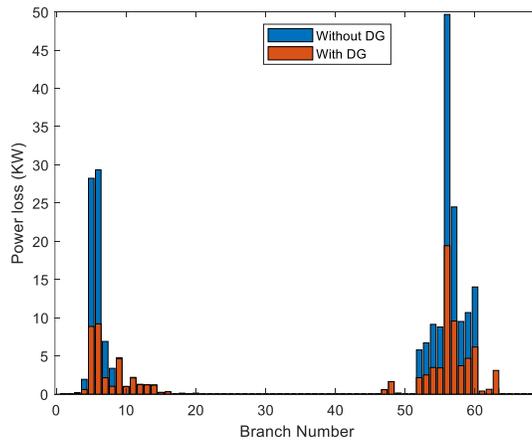


Fig 4.20 Ploss In The System Branches

C. Random Size And Location Selected Using LSF

In this case, the location was chosen based on LSF, but the difference was that in this case, just one location 61, and one size 843.5 kW were selected. Figure 4.21 depicts an improvement in the voltage profile, with the minimum value reached at 0.9420 p.u. and the loss reduced to 123.1 kW . The current and loss in the system branches and the loss in Fig 4.22 and 4.23.

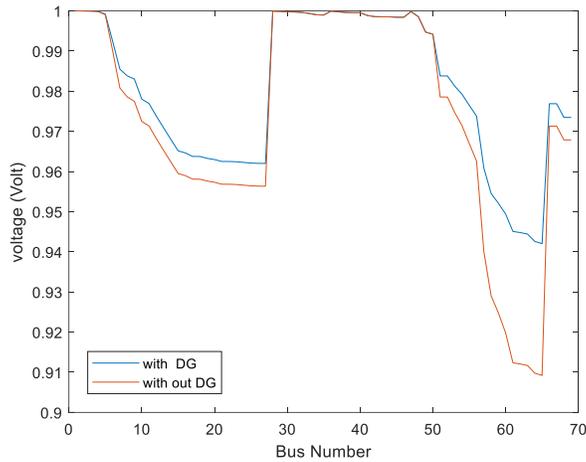


Fig 4.21 Voltage Profile

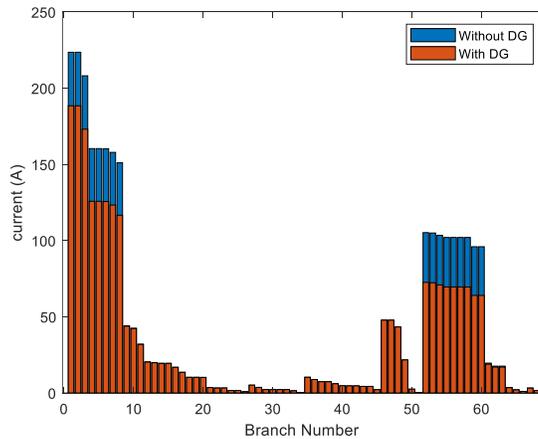


Fig 4.22 Current In The Branches

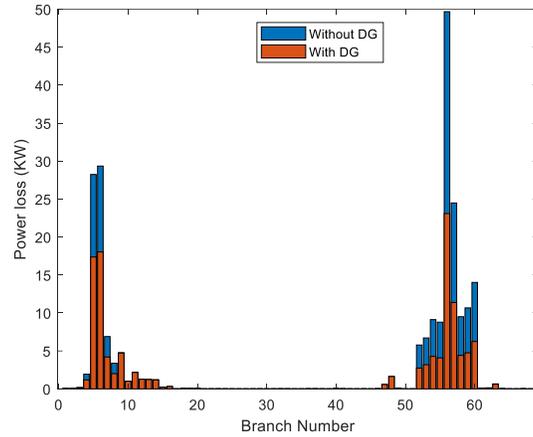


Fig 4.23 Ploss In The System Branches

4- Case 3. Random Location & Size Selected Using GA

This case is divided as follows:

A. Random Location & Size Selected Using GA

In this case, three locations were chosen randomly [44 25 15] and three sizes were chosen using GA [1575, 222, 73] kW. In terms of power losses, there are no noticeable reductions, even in terms of the voltage profile. The improvement is not as required as shown in figure 4.24. The current and loss in the system branches in Fig 4.25 and 4.26.

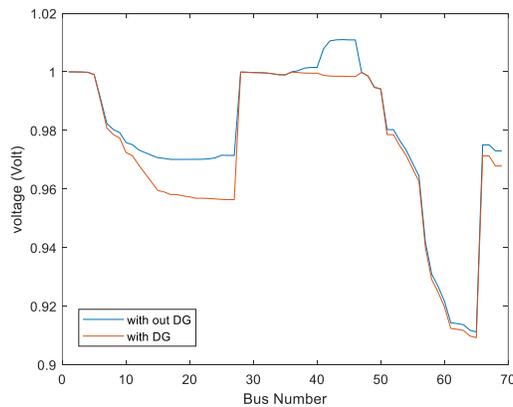


Fig 4.24 Voltage Profile

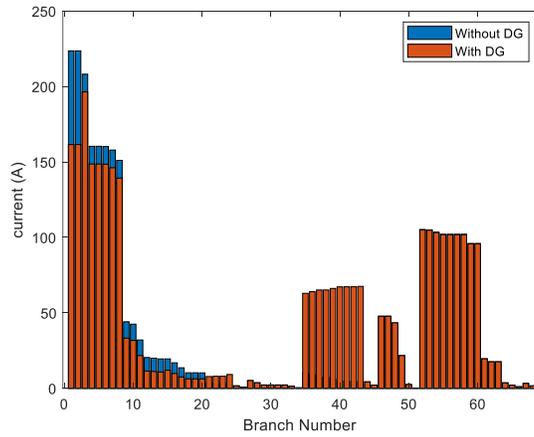


Fig 4.25 Current In The Branches

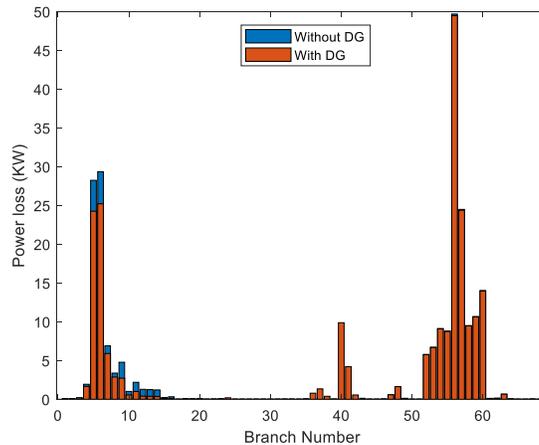


Fig 4.26 Ploss In The System Branches

B. Random Location And Size Selected Using GA

This case is like case 3. A, but here two locations and sizes were chosen. [59 45] and [1575 , 222]. From figure 4.27, we can notice that there is an improvement in the voltage profile where it reaches the lowest value of 0.9589 p.u, and the total active power loss is minimized to 102.1 KW. The current and loss in the system branches are shown below.

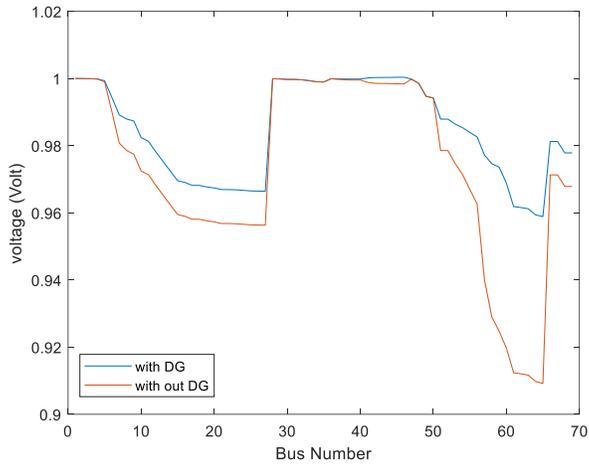


Fig 4.27 Voltage Profile

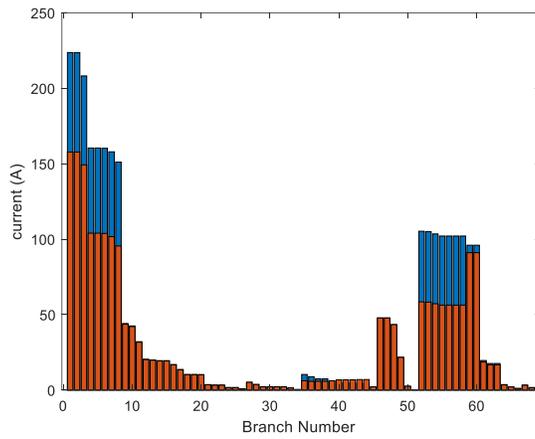


Fig 4.28 Current In The Branches

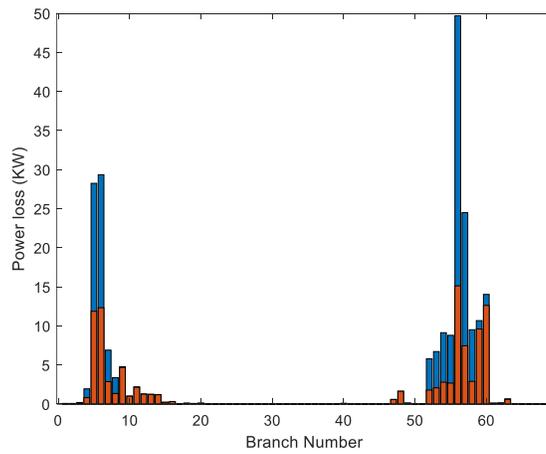


Fig 4.29 Ploss In The System Branches

C. Random Location And Size Selected Using GA

In this case, just one location was chosen (i.e., bus 55 and one size 1575 kW). Figure 4.30 shows that the voltage profile was enhanced, but not as required to exceed the lower limit of natural condition 0.95 p.u. The active power loss was minimized to 166.4 kW. The current and loss in the system branches in Fig 4.31 and 4.32.

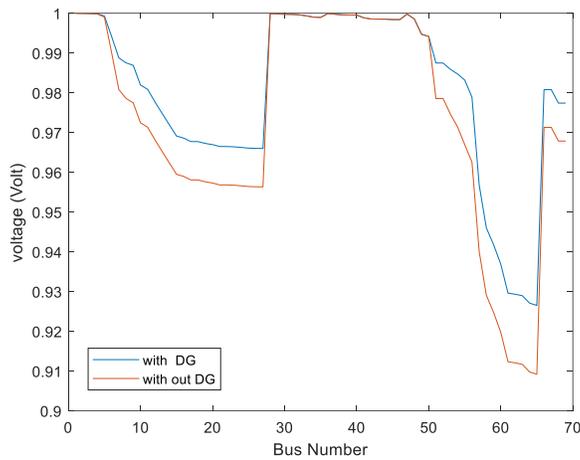


Fig 4.30 Voltage Profile

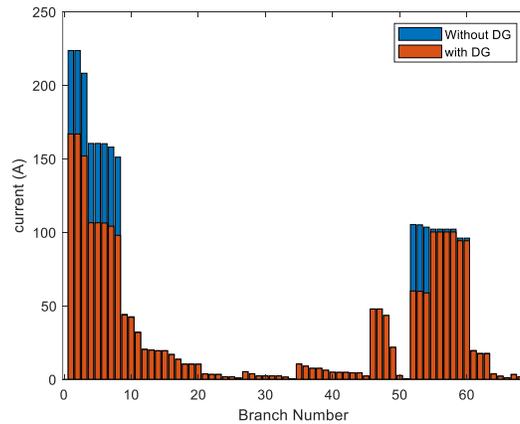


Fig 4.31 Current In The Branches

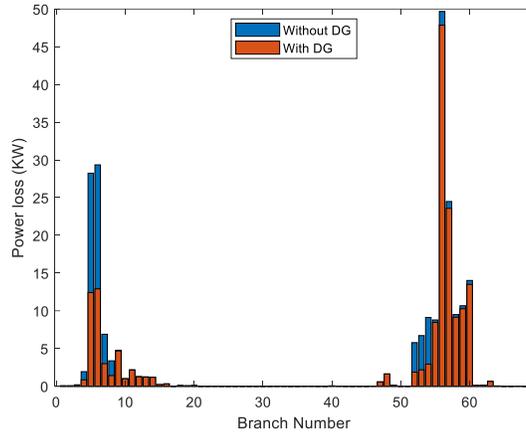


Fig 4.32 Ploss In The System Branches

5- Case 4. Location Selected Using LSF And Optimal Size Selected Using GA

A. Location Selected Using Lsf And Optimal Size Selected Using Ga

In this case, three locations were selected based on LSF [61, 64, 65] as the best locations to install the DG units with the best three sizes [1575, 222, 73] kW by the proposed algorithm, as tabulated, the active power losses were minimized to 82.6 kW and minimum voltage improved to 0.9683 p.u. The voltage profile, the current in the system branches, and the loss in the system branch in Fig 4.33, 4.34, and 4.35.

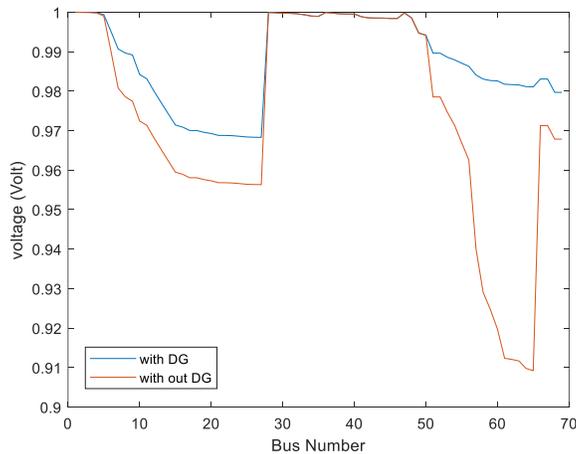


Fig 4.33 Voltage Profile

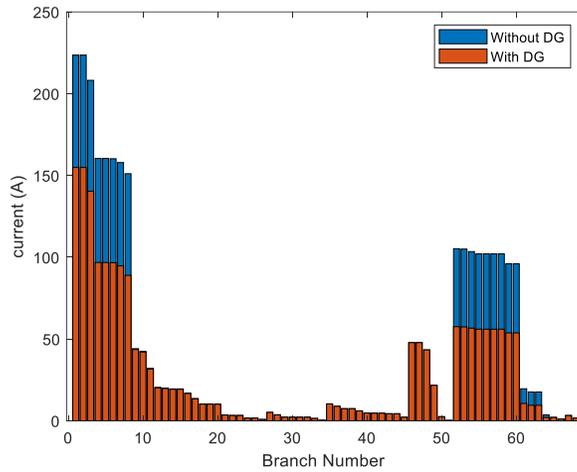


Fig 4.34 Current In The Branches

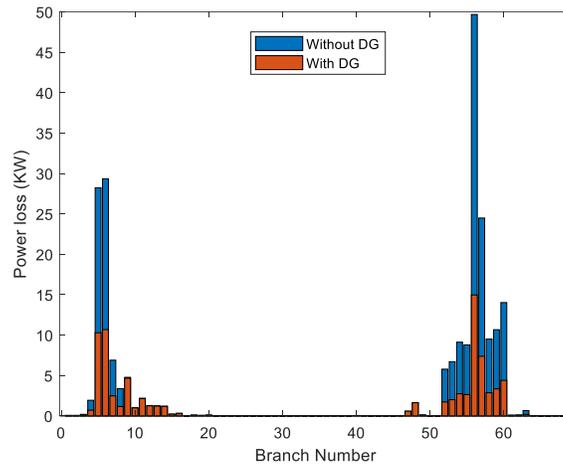


Fig 4.35 Ploss In The System Branches

B. Location Selected Using LSF And Optimal Size Selected Using GA

In this case, two locations were selected based on LSF [61, 64] and two sizes were selected by GA [1575, 222] kW. From table.1, the active power losses were minimized to 82.9 kW, and the minimum voltage was improved to 0.9679 p.u as shown in figure 4.36. The current and loss in the system branches in Fig 4.37 and 4.38.

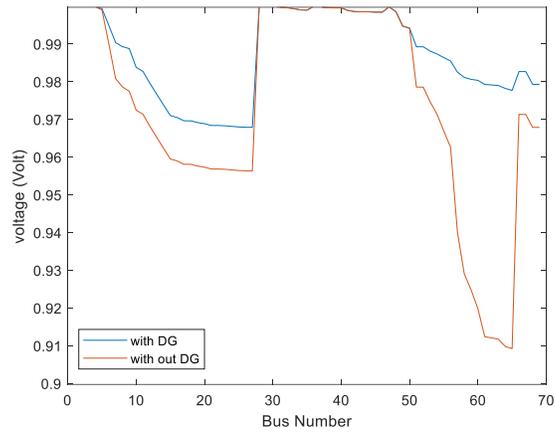


Fig 4.36 Voltage Profile

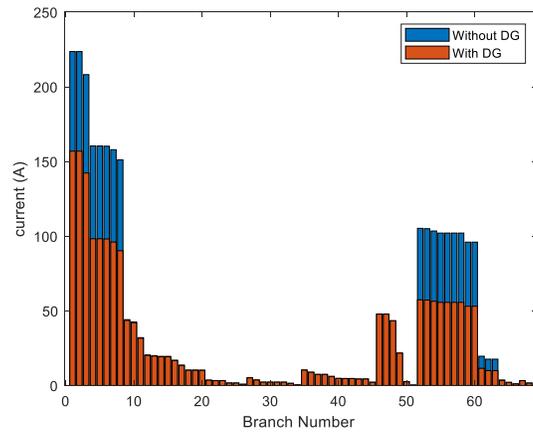


Fig 4.37 Current In The Branches

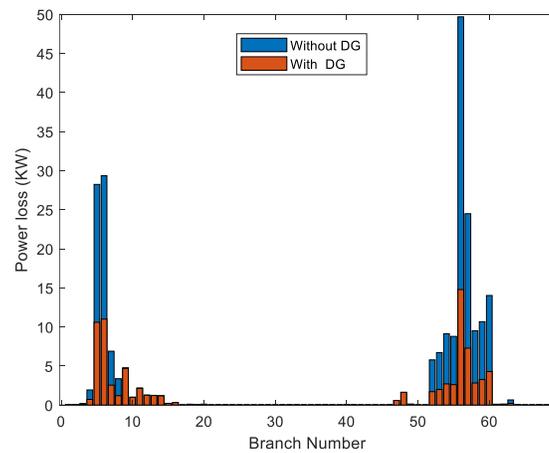


Fig 4.38 Ploss In The System Branches

C. Location Selected Using LSF And Optimal Size Selected Using GA

In this case, just one location 61 and one size 1575 kW were selected based on LSF and the proposed method. In terms of power losses, it was minimized to 86.4 kW, and the minimum voltage was enhanced to 0.9665 p.u as shown in fig 4.39. The current and loss in the system branches in Fig 4.40 and 4.41.

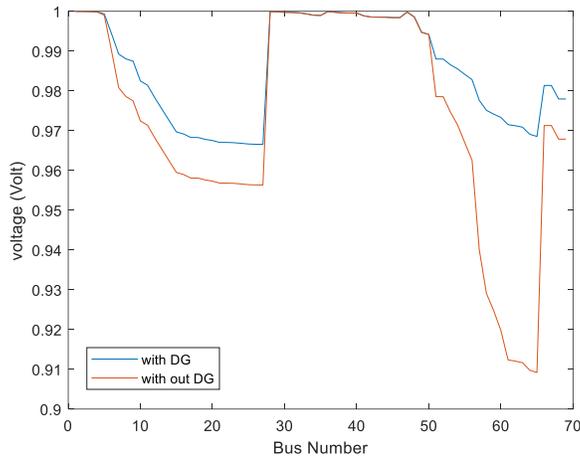


Fig 4.39 Voltage Profile

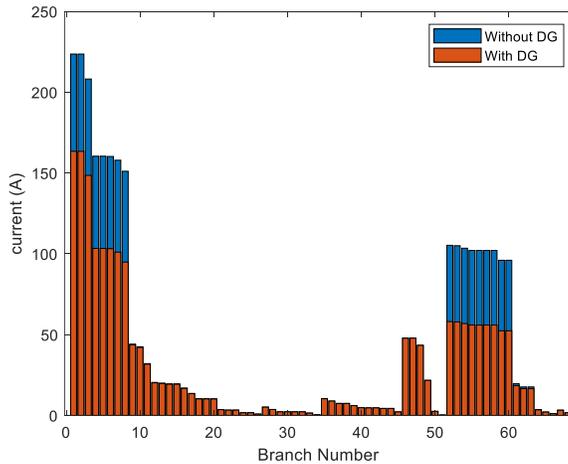


Fig 4.40 Current In The Branches

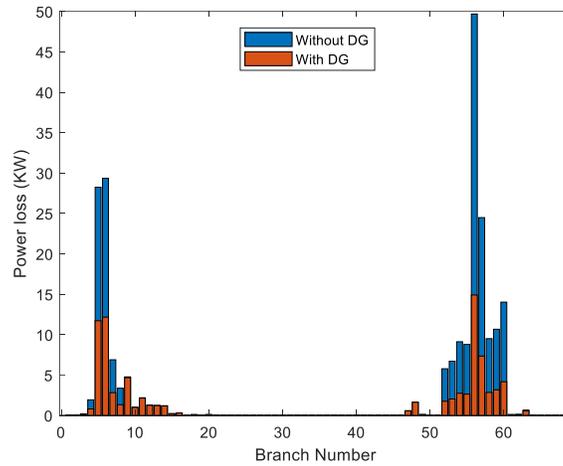


Fig 4.41 Ploss In The System Branches

Table 1 Simulation Resultes Of 69 Bus System With And Without DG

Cases	Location	size (KVA)	Ploss (kW)	Vmax (p.u)	Vmin (p.u)
Base case	-----	-----	225	1	0.9092
case1-	A - [50 41 30]	[1826.8 1264.7 195]	234.5	1.0139	0.9096
	B - [20 39]	[1264.9 195.1]	207.6	1.0119	0.9172
	C - [58]	[1500]	195.6	1	0.9187
case2-	A - [61 64 65]	[1941.2 1914.3 970.8]	371.7	1.0912	0.9836
	B - [61 64]	[1300 1100]	96	1.0036	0.9713
	C - [61]	[843.5]	123.1	1	0.9420
case3-	A - [44 25 15]	[1575 222 73]	225.1	1.0110	0.9112
	B - [59 45]	[1575 222]	102.1	1.0004	0.9589
	C - [55]	[1575]	166.4	1	0.9265
case4-	A - [61 64 65]	[1575 222 73]	82.6	1	0.9683
	B - [61 64]	[1575 222]	82.9	1	0.9679
	C - [61]	[1575]	86.4	1	0.9665

CHAPTER 5

Conclusion and Future work

The DGs in the DNs are more popular than in previous decades. As a result of the advantages of DG installation in their distribution systems, utility companies have begun to modify their electric infrastructure in order to accommodate DGs. These advantages include lowering power losses, improving voltage profiles, lowering environmental consequences, and enhancing power quality. However, realizing these advantages is heavily dependent on the ability of the DG units as well as the location of their installation in the distribution networks. The suggested method aims to find the optimal DG location using LSF and optimal size using GA. The forward/backward load flow approach is used to determine LSF. With the help of a Genetic Algorithm, the size of the DG can be optimized. The proposed approach is tested on 69-bus systems with different cases of DG location and size. Simulated results obtained show that choosing the DG location and size randomly leads to worsening system performance. But, using LSF and GA as shown in Case 4 gives the best power loss reduction and voltage profile improvement.

The management technique provided in this study is appropriate for integration into an energy management scheme in accordance with the smart grid paradigm, and the following results are attained:

1. Because of the compensation, the voltage profile is improving and losses are being reduced.
2. It has been shown that the developed algorithm is successful in understanding the allocation of distributed generators for a variety of candidate node counts and distributed generator capacities.

3. The location of DG is not advantageous in a very weak system in terms of voltage and frequency.
4. The injection process in the power system, if it is random, can make the power loss greater than it was.

We propose using active and reactive power injection to improve distribution system performance in terms of system losses and voltage improvement in future work because the DG is capable of injecting both active and reactive power.

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وزارة التعليم العالي والبحث العلمي

جامعة بابل / كلية الهندسة

قسم الهندسة الكهربائية

التكامل الأمثل للتوليد الموزع المتجدد في أنظمة التوزيع الشعاعية

بحث

مقدم الى كلية الهندسة في جامعة بابل كجزء من متطلبات نيل درجة
الدبلوم العالي في الهندسة الكهربائية.

من قبل:

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أ. م. د. سرمد خليل إبراهيم

الخلاصة

أصبح دمج (تكامل) وحدات التوليد الموزعة (DGs) ، مثل مصادر الطاقة الكهروضوئية وطاقة الرياح ، في أنظمة التوزيع ضرورة حتمية بسبب العديد من المزايا التقنية والاقتصادية وحماية البيئة. على سبيل المثال ، يمكن تحسين أداء نظام التوزيع عن طريق الاختيار الأمثل لموضع وحدات التوليد الموزع وحجمها ، مما يحسن ملف الجهد ، ويقلل من فقد الطاقة النشطة ، قد يؤدي الموقع و الحجم غير المناسب لوحدات التوليد الموزع مع مستوى اختراق عالٍ غير خاضع للرقابة في أنظمة التوزيع إلى تحديات تشغيلية مختلفة ، مثل انتهاك حدود الجهد المقبولة ، وزيادة خسائر الخط ، وتحميل المغذي المفرط ، وفشل الحماية ، وتدفق الطاقة أحادي الاتجاه ، والتصنيفات الحرارية للمعدات ، وخطأ المستويات الحالية. يدمج (يكامل) هذا العمل وحدات التوليد الموزع بكفاءة في أنظمة التوزيع باستخدام طريقة مثالية للتحقيق في أفضل موقع وحجم لهذه الوحدات . تعتمد تقنية التحسين المقترحة هنا على الخوارزميات الجينية وعامل حساسية الخسارة لتقليل خسائر نظام التوزيع وتحسين ملف الجهد مع مراعاة القيود التقنية المفترضة. تم إجراء العديد من الحالات لإظهار تأثير موقع هذه الوحدات وحجمها على أداء نظام التوزيع. تظهر النتائج التي تم الحصول عليها أن استخدام عامل حساسية الخسارة يمكن أن يسرع في إيجاد الحل الأمثل للخوارزمية الجينية. يتم تنفيذ هذا العمل على شبكة توزيع (IEEE 69 bus) القياسية باستخدام MATLAB