INVESTIGATION OF OPTIMAL POWER FACTOR IN DISTRIBUTION NETWORKS BASED ON DG PLACEMENT

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DEDICATION

This research is dedicated to my loving parents who despite the various sacrifices they made for me to achieve my goals, have been very supportive throughout. To my father who had wished that his Son should strive to be a Bachelor and above all a Master of Electrical Engineering – I shall remain eternally indebted to him. His vision and faith in me have been my source of light right through the obstacles. DAD! You are so kind to me and I can never repay you for your support and trust. All the times that you have sacrificed for me, and encouraged me have been the very motivating factor for me. I will be forever grateful to my father because he encourages me to make it even when he didn't make it for himself.

The teachings of Ahlulbayt (A.S.) are another source of great inspiration for me; his insight on the value of moral integrity and the quest of knowledge has guided me throughout my life. "*Knowledge enlivens the soul*," as Imam Ali (A.S.) once stated. Imam Ja'far al-Sadiq (A.S.) went on to say, *"The one who seeks knowledge is like a warrior in the path of Allah*." My approach to learning has been affected by their teachings, which place a strong emphasis on using information ethically in addition to its acquisition. I hope that I will always be motivated and led by their example in all that I do.

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ACKNOWLEDGEMENTS

I am very thankful to Almighty Allah for His infinite blessings and for providing me with the chance, power and capability to finish my master's degree with this thesis.

I wish to express my sincere thanks to my supervisor Prof. Dr. Asad Waqar. I would like to thank my supervisor for his constant encouragement, valuable suggestions and directions regarding this study. His commitment, love for learning, as well as efficiency in work has always been a motivation for me to work hard in this process.

I want especially to thank all the Professors whose knowledge and experience have helped in writing this thesis. I would like to appreciate my teachers for their support and contribution towards my research in form of one way or the other and my university fellows for the help they offered me in course of this research.

In addition, I want to express my deepest gratitude to my loving parents who have always been my support, my inspiration and my belief. Their support, hard work and belief in me have been the pillars that have helped me achieve my goals. I will always be grateful to them for teaching me the values which include hard work, perseverance and integrity which have been with me all through this academic exercise.

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ABSTRACT

This study optimizes Distributed Generator (DG) placement and sizing in regional distribution networks using the Sea Horse Optimization (SHO) algorithm and the Backward Forward Sweep Method (BFSM). Four distinct situations, each with a different type of DG, are used to systematically analyze the network using the Torrit software and the MATPOWER toolkit in MATLAB. The main goal is to find the ideal power factor for the deployment of distributed generation (DG), with an emphasis on active and reactive power injection and absorption. The results show notable improvements in voltage profiles and considerable reductions in power losses across a range of deployment scenarios. In addition, the study investigates how various DG types interact with one another to improve overall network efficiency. An extensive analysis comparing IESCO regional distribution networks to IEEE 33-bus and 69-bus systems confirms the efficacy of the suggested techniques. In addition, the study compares the outcomes of the SHO algorithm with those of the Artificial Bee Colony (ABC) algorithm to ascertain which method is more accurate. In summary, this research offers utility operators useful information by proposing methods to boost power system efficiency, boost dependability, and refine power distribution management decision-making procedures.

KEYWORDS: Distributed generation (DG) Backward Forward Sweep Method (BFSM) analysis Optimal sizing and placement of DGs Voltage Loss Power Factor Sea Horse Optimization (SHO).

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ABBREVIATIONS

ABC	Artificial Bee Colony
APL	Active Power Loss
BA	Bat Algorithm
BBO	Biogeography Based Optimization
BFA	Bacterial Foraging Algorithm
BFO	Bacterial Foraging Optimization
BSO	Backtracking Search Algorithm
CBs	Capacitor Banks
CSA	Cuckoo Search Algorithm
DG	Distributed Generators
EA	Efficient Analytical
BFSM	Backward Forward Sweep Method
GA	Genetic Algorithm
HGWO	Hybrid Grey Wolf Optimization
IWD	Intelligent Water Drop
IWO	Invasive Weed Optimization
LF	Load Flow
MI	Maximum Iterations
NRLF	Newton Raphson Load Flow
PSO	Particle Swarm Optimization
RDS	Radial Distribution System
RPL	Reactive Power Loss
SHO	Sea Horse Optimization
SKHA	Strud Kill Herd Algorithm

Chapter 1

Introduction

1 INTRODUCTION

1.1 Overview

The modern electrical power system is a complex network consisting of three interconnected components: There are also three main stages involved in the process which includes generation, transmission and distribution. Generating plants generate electricity and this electricity is transmitted through the transmission networks across long distances. After that, a distribution network supplies electricity to consumer directly usually organized in radial system of distribution.

The distribution network is a vital part of the national power system in Pakistan whereas it is experiencing lot of challenges. Majority of power losses are normally experienced in both primary and secondary distribution networks due to such factors as long transmission distances, low voltage conditions, technical losses, and poor power factor control.

In view of the growing population that comes with urbanization and industrialization, electricity demand increases and hence the pressure on the distribution companies to deliver efficiently. Distribution networks are complex, and thus the operation of distribution networks is likely to cause system instability, increased power dissipation and voltage fluctuations due to high current loads during distribution.

As this thesis’s overview demonstrates, distribution networks remain a key component of Pakistan’s energy system, and that authoritative changes are required to improve the distribution infrastructure, robustness, and reliability in the power sector.

1.2 Motivation and Problem Statement

To illustrate this let us think of the electricity system in your neighbourhood. It is similar to the electrical power system where there are many wires that bring power to your home. Today, we are integrating small power producers such as PV panels, wind farm and others in this system. It is eco-friendly, however, it still has its challenges sometimes. The issue which I am attempting to address in this study is how to place these small power sources in the right positions and ensure that they are of the right size. This is something we would wish to achieve so that there is no wastage of electricity and all systems run as supposed to. Occasionally, the electricity can become a bit complex and we would like to improve it. Another way that one can know the performance of the electricity system is something called the “power factor” This should ideally be 1:1 but it is never exactly like that. We also need to reduce losses as electricity flows through the wires so that we do not use up all the energy that is being transmitted.

Distributed generations or DG systems have been integrated at the distribution networks, which have affected their operation and performance. There are several advantages that can be achieved through the use of DG resources and these include; Improvement of power quality within the network, and minimization of system loss. In this regard, one of the important issues that are important to address is the use of DG and its size for maximizing power factor in distribution networks.

The power factor is one of the most important parameters affecting the effectiveness of power distribution as well as its quality. This in turn causes high losses, voltage drop and a poor overall network performance due to low power factor. Thus, the primary purpose of this study is to address the following question: ‘How can DG units be sized and located properly in distribution networks in order to achieve the least losses and the best power factor?

The progressive increase in the electrical load demand in the last few decades has added to the total line losses and voltage drops in distribution systems as compared to the transmission systems since their X/R ratio is lower [1]. In the past, the number of networks has been used as the conventional way of addressing these problems [2]. However, it has been realized that about 80% of the added infrastructure is underused as most of them are designed to meet peak load requirements that are only valid for 5% of the total working time [3].

Over the years, many methods have been introduced to mitigate the problems associated with power loss and voltage drop such as proper positioning of capacitors and injection of reactive power. Although capacitor bank placement seems to hold a lot of potential for the said methods, they do not usually offer voltage profiles that are above the nominal value of 1 p.u., primarily because of the passive nature of radial distribution systems. As a result of this inherent passivity and in order to achieve the goal of minimizing voltage drop, several approaches have been proposed among which is the incorporation of renewable energy sources known as Distributed Generation (DG).

Distributed Generation technologies have become popular due to the flexibility of installation and short time of response [4]. Sized and located appropriately, DGs have been proven to reduce tremendously line losses and voltage drops in electrical grids. Thus, both as generators of active power and as reactive power suppliers, DGs can be useful load that assists in reducing peak load demands; in turn, it makes it possible to dampen pulsing loads, minimize power losses and improve the stability of the power factor [5]. These are some of the complex issues that make the planning of the size and location of DGs in distribution networks very systematic, and for this reason, this thesis focuses on the following.

It is impossible to facilitate working electrical substation-connection distribution networks with or without Distributed Generators (DGs) which are vital in determining power factor optimization/size/placement. Thus it can be summarised that improvement of power factor is required for efficient operation of power transmission and distribution network. Distributed generators (DGs) playing a vital role in this regard since they can actively control reactive power which offsets the imbalance caused by inductive loads such as motors and transformers. DGs reduce the associated transmission losses that are usually experienced due to low power factor and also help in controlling and balancing of voltage by providing reactive power as a needed. DGs are categorized based on the power that is in the form of either reactive or active power that an islanded DG can consume or supply. The following are the four DG classifications:

Active Power Injection or Type 1 DG Just Solar photovoltaic (PV) systems are known as type 1 DGs these mainly inject active power (P) to the grid. Solar photovoltaic systems directly inject electrical power generated by sunshine to the distribution network. Reactive power is not generally produced by these systems in any isolated manner. For this reason, they are considered to be responsible for no contribution to the management of reactive power of the system but are only involved in the generation of active power.

Reactive Power Injection, or Type 2 DG As for any capacitor bank type 2 DG inject reactive power (Q) to the system. They include the control of voltage by use of reactive power and ensuring that satisfactory power is available in the network. Capacitor banks to be connected in the system for controlling the amount of reactive power can be connected in the system according to the requirement. They assist in interlinking the PF and voltage regulation by providing for required short in the distribution network.

Active and Reactive Power Injection, type 3 DGs can inject power both in terms of real power (active power ‘P’) and Reactive power ‘Q’. Examples of such equipments are Synchronous machines and certain types of wind power turbines. Due to the flexibility in the design of synchronous machines, they can be tailored to alter the amount of reactive and real power which is generated as one deems fit. In addition, this capability helps them to participate in creation of active power and to support stability of the grid by providing reactive power if required.

Active Power Injection with Reactive Power Absorption is Type 4 DG. The 4th type of DGs impose both active power (P) into the grid and absorb the reactive power (Q), for instance, wind power producers using Induction generators. For the purpose of running induction generators used in wind turbines, reactive power has to be taken from the grid. Therefore, they supply reactive energy which the distribution system has to obtain from other sources in order to maintain the voltage stability with the necessary reliability.

In this thesis, four types of DGs are introduced as follows: Each of which plays a specific role to improve and steady distribution networks with its respective advantages. With proper size and location of these DGs, it has been reported to reduce line loss up to 50%, produce optimum voltage profiles and enhance the efficiency and reliability of the grid. To fully harness such advantages whilst at the same time reducing the total energy costs and power losses, this thesis analyses the most suitable method for incorporating these DG kinds.

Achieving an ideal capacity for DG installation requires correlation with load demand in the various regions and voltage stability. This ensures that DGs to be employed are optimally used in meeting the requirements of the reactive power. Some types of inverters and some synchronous DGs may change their output voltage so as to maintain constant power factors which in turn enhance the systems performance in general. Intentionally sited DG systems are efficient since they minimize loss as they distribute energy and at the same time increase stability of the electricity grid.

In addition, DGs are self-inherently contributing to high power-factor qualities particularly when they derive from sources such as solar and wind. With the reduction of fossil base DGs, incorporation of these renewable distributed generation units (DGs) in the grid also enhances the environmental quality, while at the same time enhancing voltage control and grid stability.

1.3 Objectives

The objectives of this research is to improve the sustainability, dependability, and efficiency of power distribution networks. These objectives address significant aspects of network transmission in order to optimize distribution system performance. Research endeavors to enhance the resilience and efficiency of the electrical infrastructure by mitigating power losses, augmenting power factor, and maintaining constant voltage levels.

. The following are the main goals:

- Minimization of Active Power Loss (APL)
- Minimization of Reactive Power Loss (RPL)
- Improvement of Network Power Factor (PF)
- Minimization of Voltage Deviation Index (VDI)

These objectives collectively aim to optimize distribution network performance by addressing key challenges in power management and system efficiency. Achieving these objectives will enhance operational reliability, reduce environmental impact, and support the transition towards a more sustainable energy future.

1.4 Limitations

The limitations always occur with some extension:

- **Limited Data Availability:** Access to comprehensive and up-to-date data on network topology, load profiles, and operational parameters from IESCO's distribution networks may be restricted due to privacy and regulatory concerns.
- **Data Consistency and Accuracy:** Variations in data quality, such as incomplete datasets or measurement errors, can impact the reliability and precision of research findings and modelling outcomes.
- **Temporal and Spatial Resolution:** Data granularity, both in terms of temporal (time intervals) and spatial (geographical detail), may be insufficient for detailed analysis. Some IESCO grids still note and calculate data manually, which weakens accuracy and reliability.

1.5 Organization of Thesis

This thesis research consists of following chapters:

- Chapter 1 reviews introduction of the power system, motivation & problem description, objectives, limitations and organization of dissertation.
- Chapter 2 describes the literature review.
- Chapter 3 describes Backward Forward Sweep load flow analysis and mathematical mode of radial distribution.
- Chapter 4 explains the proposed SHO algorithm in comparison with ABC algorithm.
- Chapter 5 details the test system and the results obtained after the implementation of algorithm.
- Chapter 6 summarizes the conclusions and some future works.

Chapter 2

Literature Review

2 LITERATURE REVIEW

If distributed generation (DG) units are to reduce power losses and enhance voltage profiles, they must be scaled and placed in distribution networks in compliance with best practices. The connection between system performance and the DG power factor has been the subject of numerous studies.

There was a proposed flow placement, sizing, and power factor concerning several units of DG that utilized the Differential Evolution algorithm. The authors also pointed out that, compared to those DGs that have a unity power factor, the DGs which have a lagging power factor have proved to be more effective in terms of losses and voltage profile [1]. Another research presented an analytical index, which incorporates reliability-based index, voltage stability index and loss sensitivity factor to decide the precise location and size of the distributed generators. The application of the proposed index was tested and analyzed on IEEE 33 and 69 bus distribution systems to show the impact of DGs at leading power factor on the network reliability and voltage stability [1].

A study was therefore conducted with the objective of reducing power losses and enhancing the voltage profile by ascertaining with high accuracy the precise location and size of DG units by using three major indices, the IVM (Index Vector Method), VDI (Voltage Deviation Index), and VSI (Voltage Stability Index). The two types of DGs which the authors considered were the lagging power factor and unity power factor. They realized that it was the larger DGs that had the best overall outcome as far as minimum bus voltage and losses were concerned if operated at a power factor of 0. 9 and the VSI index the findings showed that the global gender gap report, the human capital index, and the VSI index were all correlated with each other. [2]

Another study investigated the places that are suitable for DG in various forms inside distribution networks. This was made possible because the authors managed to keep the total power distribution loss as small as possible to determine the most appropriate size and location of DGs. They also found that the quality of the supply to the DG also has an effect especially the ideal power factor of the system. [3]

There is another study which described how actual power losses can be minimized in primary distribution networks using distribution generators in an optimal way through employing reactive power and active power compensation particle swarm optimization method. The right power factor was also quantified in order to minimize energy loss. Thus we can state that the analytical technique can be applied for smaller systems to determine the optimal size and location within the system as for each system bus, the technique offers the best solution. Heuristic approaches are again better suited for the larger systems since the search of a solution is faster. [3]

The loss sensitivity factors method is employed to identify potential sites for Distributed generation (DG) which depends with the node's loss and their sensitivity after compensation. Therefore, the positions for distributed generators which should be connected in the system are identified as those which cause the highest bus real and reactive power losses. As mentioned before, when DG are integrated into the distribution system, the buses with high losses minimize the level of losses. [3]

How to place DG optimally; the placement of DG to minimize active power losses in the distribution networks has been the focus of many researchers. A new and versatile voltage stability index was proposed in one thesis to determine both the conductor stability limit as well as the optimal conductor size. Optimum switching configuration for a microgrid, according to the authors, were arrived at through reconfiguration with the help of BAT method thereby minimizing the loss of active power. Further, the proposed BAT algorithm was used to identify the ideal position and sizes of DG sources for better stability and minimized power loss. [4]

Another study provided a very effective method for reducing total power losses in distribution networks adding PV systems coupled to capacitors. From the obtained outcome it can be inferred that apart from the reduction of loss through the installation of capacitors, the installation of PV system may contribute significantly to the reduction of loss, as well as the number of capacitors installed [5].

The literature has also analyzed of how capacitors influence the minimization of power loss. One research has shown that the two factors that affect the reduction of the active power losses are load reactive power and capacitor capacity. To avoid increase of the overvoltage and the power losses, the size of the capacitor should be varied from zero to the reactive power of the load but not more. The contribution of the researchs also highlights the importance of the network power factor on the distribution network performance in the literature. One of the solutions after analyzing and comparing for the active power transmission loss allocation in power pools was that a method for improving the power factor at the network level [6].

Another factor that must be considered when placing the DG units at an optimal locations is the voltage fluctuations. To determine the conductor diameters needed for the best results and conductor stability limit, a study proposed a new voltage stability index. According to the authors, to minimize the voltage deviation index, the best switching arrangements together with the best DG locations were defined by using a BAT algorithm [6].

Here, load requirement is designated to increase significantly, which in turn makes the network more sensitive to voltage fluctuations. Apart from increas-ing the conductor size ‘reconductoring’, applying higher voltage levels, inducting capacitors, and network reconfiguration are some of the techniques that are applied to reduce or even eradicate such losses. Distributed generation (DG) systems can help in enhancing the voltage level and combating power outages at the same time and add efficiency to the distribution network [7]. DGs are located in the distribution network. The integration of distributed generation (DG) units in distribution networks has recently increased and this lead to an analysis of the effects of such units on the power grid from the environmental, technical and economical perspective.

The literature reveals that it is possible to have multiple techniques for allocating DGs into various distribution grids in an optimal manner. For the optimization of the size and the location of DG the authors employed the genetic algorithm (GA) inspired by nature in [8]. The goal and that is, reducing loses, has been achieved by the author. The authors have evaluated the performance of the presented method for IEEE 16, 37 and 75-bus distribution system. To find the optimal location of multiple distributed generators (DGs) in a microgrid, the authors in [9] have presented an improved re-initialized socially structured particle swarm optimisation technique known as IRS-PSO. The authors have applied the proposed method on IEEE 69-bus radial distribution system.

Most of the authors in [10] proposed the use of the sensitivity test technique to identify where and of what size to locate the DGs. The lone goal, that is to reduce power losses, has been achieved perfectly by the author. The authors have applied the given approach on IEEE 33- and 69-bus systems. A new heuristic algorithm of the optimized sizing and positioning of a single DG using an artificial bee colony (ABC) has been developed to minimize power loss in the system. The authors have evaluated the proposed method in IEEE 33 and 69-bus systems and states that new method is much better than PSO and GA with varying parameters [11].

Several DGs' placement was optimized in [12] by utilizing hybrid grey wolf optimization (HGWO). The authors' single aim of minimizing the power loss was achieved when the authors applied the proposed method on the IEEE 33, 69 and Indian 85-bus radial networks. According to authors [13], BA is the best approach to provide the optimal PV power assignment. This is the real power loss and the authors endeavour to decrease its value. Implementation of the proposed approach was carried out on IEEE 33-bus distribution model. In [14], the authors applied particle swarm optimization (PSO) method in the allocation of capacitors and DGs. It was to make the highest level of profit as could be envisaged in a given period. IEEE 33 and 69 Bus distribution networks were used to assess the effectiveness of the presented technique.

Many DGs positioning was studied in [15] using the strud krill herd algorithm (SKHA). The authors have achieved their set objective of minimizing line loss, and they have tested there proposed method for test being the 33, 69, and the Portuguese 94 buses in radial distribution grid. The authors of [16] introduced the augmented PSO approach that was used to determine the location of the DGs that provides the best combinations of parameters as shown below. It was for the purpose of making the maximum amount of profit possible. The above-discussed method is proposed on an IEEE 34-bus electrical distribution network. In [17] the authors used PSO to assess the impact of DG location and size. The authors had the main goal of minimizing the cases of power interruptions. The effectiveness of the proposed technique was investigated for IEEE 33 and 69-bus systems.

The authors in [18] have used bat inspired algorithm (BA) to maximize the size and placement of a stand-alone DG. The methodology proposed in this research was simulated on test power networks namely the IEEE 33 and 69-bus networks. In [19], a PSO and gravitational search method-based population structure was proposed to address the issue of optimal sizing of DGs as well as their location in the distribution network. In [20], the authors have used bacterial foraging algorithm (BFA) to allocate DGs in different models such as IEEE 12, 34 and 69-bus distribution models effectively. The objectives that were set aimed at a higher bus voltage and a reduction of the power losses. Whereas, in [21], it was revealed by adopting an efficient analytical (EA) technique that the best distribution of all the various DGs. Such type of losses are called no load losses or losses that occur even when there is no current passing through the transformer.

Authors in presented a genetic algorithm (GA) for the optimal placement and sizing of diode generators (DGs) and capacitor banks (CBs) [22]. The two main objectives were power loss reduction and reliability. The proposed approach was verified in IEEE radial systems. One technique for placing PV arrays is biogeography-based optimization (BBO), as proposed by the authors in [23]. The sole objective is to minimize power loss. The proposed optimization method was evaluated in IEEE 33 and 69-bus radial systems. Harmony Search Algorithm (HSA) has been employed by authors to simultaneously find the DG optimal site and reconfigure the network by using power loss minimization as the only objective function [24].

The authors in [28] have proposed a hybrid method (HA) to appropriately size and place DGs. The DGs were placed by PSO, and their size was tuned through analytical techniques. The proposed method was assessed using standard IEEE networks. The objectives were to improve the voltage profile and decrease total power loss. As proposed by the authors in [29], one technique for determining the optimal location and capacity for DGs is backtracking search optimization (BSO). The proposed technique was tested on radial networks with Portuguese 94-bus and IEEE 33-bus traffic. The objective was to minimize power loss and voltage drop.

Bacterial foraging optimization (BFO) was used in [30] to propose the placement and dimensions of a single DG in the IEEE distribution system. Lowering active power loss, operating expenses, and voltage drop were the objectives. Natural intelligent water drop (IWD) optimization has been proposed in [31] to optimize the placement of DGs. The proposed optimization method is tested on IEEE 10, 33, and 69-bus radial grids. The objective was to lower total line loss.

None of the examined research have explicitly looked into determining the ideal power factor for placing distributed generation units, despite the fact that the published literature offers a variety of optimization strategies for this purpose. Most research has concentrated on goals such voltage profile enhancement and active power loss minimization, ignoring the effect of DG power factor on system performance. In order to close this gap, the current work suggests a novel way for deciding on the best location and size of distributed generation units (DG) units while taking their power factor into account.

This approach is based on the sea horse optimization (SHO) algorithm and the Backward-Forward Sweep (BFS) method. The BFS technique is used to efficiently assess the power flow in radial distribution networks, while the SHO algorithm is used to optimize the placement and sizing of distributed generators (DGs) with respect for power factor as a vital parameter. By integrating the power factor as a crucial element in the optimization process, the proposed method aims to provide a more comprehensive and workable solution for the optimal placement of DG units in distribution networks [32]. Better power loss results are expected when comparing the BFS-SHO method to other existing techniques that do not explicitly account for the impact of the DG power factor.

2.1 Discussion on Literature Review

It is evident from the literature review that most of the research focus on DG placement and sizing to minimize the power loss or/voltage profiles or both using various techniques. The goals are comprised in a broad range of objectives to enhance the performance of the distribution network as listed below; minimise active power loss (APL), minimise reactive power loss (RPL), improve the network power factor (PF), and maximise the voltage deviation index (VDI). Combined, these objectives aim at enhancing operational reliability, minimizing impact on the environment and towards the implementation of low carbon economy. Achievement of these goals will go a long way in improving the efficiency of the system and management of power. [32]

To achieve these goals, the thesis employs the advanced Sea Horse Optimization (SHO) algorithm, a newly developed technique, as a new approach for searching for useful solutions based on the actions of seahorses when foraging for food. Many variations of the SHO algorithm in the search patterns, which enables the addition of diverse solutions and reduce the parameter of local optimization. The conventional Artificial Bee Colony (ABC) algorithm, which is a swarm intelligence-based method inspired by bees’ foraging process, is also employed for comparison purposes. Thus, the limit cycle capacity of the ABC method increases solution variety by decreasing the possibility of local optimization [33].

Furthermore, the Sea Horse Optimization (SHO) algorithm was employed at first in two analyses. The first analysis concentrated on minimizing the four objectives in IEEE 33-bus and 69-bus radial networks, as well as some regional distribution networks, such as those of IESCO: Active power loss (APL), reactive power loss (RPL), correction of network power factor (PF) and voltage deviation index (VDI). These outcomes were then compared with the outcomes of other preceding used algorithms such as the Artificial Bee Colony (ABC) algorithm. The ABC method was also applied in the second analysis to respond to the same goals mentioned above. This was possible because both studies were conducted across all the four categories of DGs thus ensuring an effective assessment of the DGs.

Chapter 3

Methodology

3 METHODOLOGY

The approach combines the Backward-Forward Sweep (BFS) method and the Sea Horse Optimization (SHO) algorithm to achieve key objectives: Minimizing active power loss which is signified by APL, decreasing reactive power loss which is abbreviated as RPL, increasing the power factor of the network which abbreviated PF and lastly maintaining a Voltage deviation index abbreviated as VDI.

The performance of the proposed methodology is confirmed by comparison with the recognized IEEE 33-bus and IEEE 69-bus radial distribution networks. Further, the methodology will be employed on the regional distribution networks supplied by IESCO to have a practical implementation aspect in the study.

For load flow analysis in radial distribution networks, the BFS method will be used and for identification of DG placement and sizing the SHO, which is inspired from the foraging behavior of seahorses will be used. Another algorithm for comparison with the results is the Artificial Bee Colony (ABC) Algorithm as well.

The optimization process will involve using objective functions that will define the outcome metrics to be optimized such as the active power loss, reactive power loss, network power factor and the voltage deviation index.

To further prove the concept, the methodology will be conducted across a variety of DG units to demonstrate the versatility of the methodology to different power factor operating limits. Ideas from the SHO and ABC algorithms will be discussed in the context of other optimization methods for the clarity of the usefulness of the proposed method. The effectiveness of the presented methodology will be showcased in more detail by applying it to distribution networks of IESCO.

This work gives an overall method that offers a framework of analyzing and enhancing DG distribution into networks with custom designed power factor. Through the use of state-of-the-art optimization methodologies and highly detailed simulation models, the proposed research is expected to increase network performance, decreased running expenses and produce a more reliable system.

3.1 Objectives to be minimized

Reducing reactive power loss, cutting active power usage, and raising the network's power factor are the goals of the optimization task. **OBF** is the notation for the objective function. The values of the weights ***W1,W2,W3*** and ***W4*** are all equal at 0.25. The index for active power loss is called **APL**, the index for reactive power loss is called **RPL**, the index for Voltage Deviation Index is **VDI** and the network power factor index is called **PFI** [35]**.**

$$\mathrm{OBF} = w_1 \cdot \mathrm{APL} + w_2 \cdot \mathrm{RPL} + w_3 \cdot \mathrm{VDI} + w_4 \cdot \mathrm{PFI} \qquad (3.1)$$

3.1.1 Active Power Loss

The first objective is minimization of total active power loss P_{loss} (kW), Where, P_{loss} is total active power loss in kW. APL is defined as the ratio of active power loss after the allocation of Distributed Generators (DGs) to the active power loss before the allocation of DGs. Active power loss refers to the energy that is lost as heat in electrical power systems, primarily due to the resistance of the electrical conductors (like wires and transformers) that carry the current. This type of power loss occurs when electric current flows through a conductor with resistance, causing energy to be dissipated as heat according to Joule's law. The formulation is given by [36] :

$$P_{loss}(i,j) = R_{ij}.\frac{(P_i^2+Q_i^2)}{|V_i|^2} \qquad (3.2)$$

$$\mathrm{APL} = \frac{\mathrm{APL_{after\_DG}}}{\mathrm{APL_{before\_DG}}} \qquad (3.3)$$

3.1.2 Reactive Power Loss

Reactive power loss is prevalent in power systems because all systems contain inductive and capacitive components that generate both real and reactive power. While the active power is the power that actual performs useful work, the reactive power is that which needed to sustain the voltage levels required in the power system, but in itself does not deliver energy to the loads. Reactive power loss results into poor efficiencies in the power system as the current flow in the network increases leading to I²R losses or active power loss and increases the need for capacities equipment.

Several methods of power factor improvement can be applied, and one of the most important measures connected with reduction of the reactive power loss is increasing of the value of the power factor in the sense of the ratio of the active power to the apparent power. A low power factor means that a large proportion of the power is reactive and results in larger currents and, therefore, higher losses in the system. Reducing the real power and increasing the apparent power, power factor can be improved while use of equipments such as capacitors or synchronous condensers can help in removing most of the reactive power in the system. Not only does this, it also minimizes the overall current within the system and; therefore, the active power loss as well. Therefore, ensuring an improved power factor optimizes the utilization of power equipment to reduce energy consumption, enables power companies to limit infrastructure development by only having to upgrade instruments, which are overburdened by power factor related challenges. Reactive power loss after DG allocation is defined as the total amount of reactive power loss after the distribution of the integrated Distributed Generators (DGs), and the overall reactive power loss before the distribution of the integrated DGs. [37].

$$Q_{loss}(i,j) = X_{ij}.\frac{(P_i^2+Q_i^2)}{|V_i|^2} \qquad (3.4)$$

$$\text{RPL} = \frac{\text{RPL}_{\text{after\_DG}}}{\text{RPL}_{\text{before\_DG}}} \qquad (3.5)$$

3.1.3 Voltage Deviation Index

The Voltage Deviation Index (VDI), is an important integer in power systems which coincides with the extent of deviation of voltage levels from their intended nodes. Hence, if voltage deviation is allowed to occur and is allowed to persist, it will have adverse impacts on the operation and effectiveness of an electrical distribution network. when power factor improving measures are used like; proper placement of distributed generations or use of capacitor, the amount of reactive power in power system is regulated. Such negative reactive power flow is constrained when the flow of the reactive power is reduced and this results to controlled voltage in the electrical network. As a result a lower Voltage Deviation Index is likely to be achieved meaning that the Voltages at various points in the power network is smaller and closer to the optimum. Another implication of a lower level of VDI is better PF implies more sinusoidal voltage and current waveforms – no under-voltage, over-voltage, which are some of the biggest challenges to the efficiency of electric energy and possible failure of electrical appliances. Therefore, it can be seen that measures that lead to an improvement in the measure of the power factor are advantageous in minimizing voltage fluctuations thereby enhancing the stability of the power distribution network. As stated, n is the total number of buses in the system, V_b is the bus voltage after placement of DG in the system and V_{ref} is any reference voltage ~ 1. 03 p. u. The formula that can be used to show VDI is as indicated below. [37]

$$VDI = max_{\{b=1\}}^{\{n\}} \frac{\{|V_{\{ref\}}| - |V_b|\}}{|V_{\{ref\}}|} \qquad (3.6)$$

3.1.4 Network Power Factor Index

Measures of the power factor at the network level Determine Network Power Factor Index, otherwise known as PFI are critical in the electrical distribution network. Power factor is the real power which may be used to do work or to deliver useful work to the product of real and reactive powers that flow through the circuit. Figure 8 reveals that higher power factor closer to unity is suggestive of efficient use of electrical power on the other hand a lower value indicates inefficiency due to utilization even of non-productive or reactive power which does not do useful work but adds to the total apparent power and hence more losses.

Optimizing the power factor at the network level enable the enhancement of the efficiency of the power distribution network. From the table, when the value of the power factor is improved (closer to the value of 1) then it observes a higher PFI which is an added advantage in terms of efficiency and reduction in the use of reactive power. This improvement can be made by some techniques like inserting capacitors or synchronous condensers or Also, the location of Distributed Generation (DG) units can be effectively adjusted. Lower KVAR means that lesser current is required to supply the same amount of real power that in turn reduces the amount of I^2R losses (active power loss), reduces the load on the transformers and conductors and hence decreases energy costs and increases the stability of the system.

The PFI, therefore, functions as an indicator that utilities use in efforts to fix the power issue at the networks, hence enhancing effectiveness and reliability. PFI is calculated using the following relation:PFI is calculated using the following relation: [34]:

$$\mathrm{PFI} = 1 - \mathrm{PF}_{\text{with\_DG}} \tag{3.7}$$

The Network Power Factor with DGs.

$$\mathrm{PF}_{\text{with\_DG}} = \frac{P_g + P_{dg}}{S_{\text{with\_DG}}} \tag{3.8}$$

$S_{\text{with\_DG}}$ is the apparent power of the network after the allocation of DGs and is defined as:

$$S_{\text{with\_DG}} = \sqrt{\left(P_g + P_{dg}\right)^2 + \left(Q_g + Q_{dg}\right)^2} \tag{3.9}$$

The Network Power Factor without DGs is formulated as:

$$\mathrm{PF}_{\text{without\_DG}} = \frac{P_g}{S_{\text{without\_DG}}} \tag{3.10}$$

$$S_{\text{without\_DG}} = \sqrt{P_g^2 + Q_g^2} \tag{3.11}$$

3.1.5 Optimization Constraints

This optimization problem is accompanied with a number of constraints such as load flow balance, voltage constraints on buses and DG’s output constraints. Total real and reactive power supplied to the network together with that from DGs must be equal to the connected load and total power losses:

$$P_g + \sum P_{dg} = P_{\text{load}} + P_{\text{losses}} \tag{3.12}$$

$$Q_g + \sum Q_{dg} = Q_{\text{load}} + Q_{\text{losses}} \tag{3.13}$$

The power output of the DGs must not exceed the total connected load limit:

$$0 \le P_{dg} \le P_{\text{load}} \tag{3.14}$$

3.2 Load Flow Analysis

3.2.1 Backward Forward Sweep Method Analysis

The Backward-Forward Sweep (BFS) method is a cornerstone in the current work as we employ it to study the power flow characteristics of distribution feeders of a region. This conventional numerical method allows the studying of nodal voltage and power flows which are critical in analyzing the effects and benefits of introducing DGs and shunt capacitors into the grid. At its core, the BFS method entails two main steps: two main components which are the forward sweep and the backward sweep. When operating in the forward sweep phase, the algorithm systematically goes through each node in the network starting with the node where the electric power originates and ending at the load terminals. Finally, when convergence is reached the use of the BFS method allows for determination of the power flow in the branches and nodes of the network. This kind of analysis is critical in determining information such as the power losses and voltage profiles which is important when assessing the effectiveness of power factor improvement methods like placement of DGs and shunt capacitor [35].

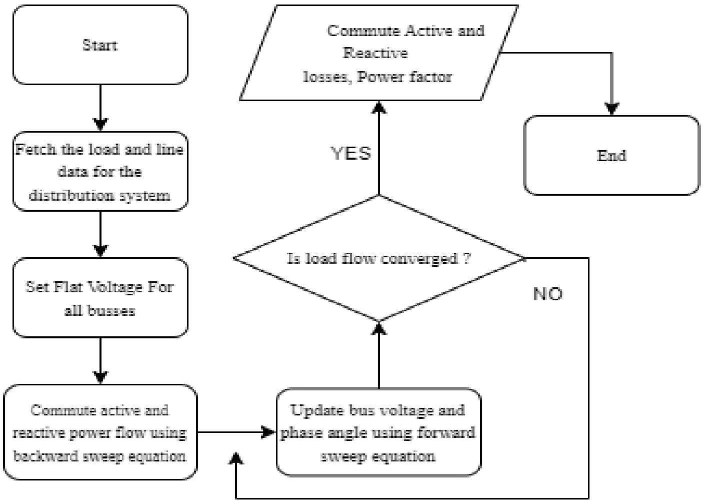


Figure 1 Flowchart of Forward Backward Sweep (FBS) Method

For radial distribution networks, particularly characterized by a radial structure, low X / R ratio, and weakly meshed design, the BFS method is used in load flow analysis owing to its high efficiency [6]. Opposed to Gauss-Seidel and Newton-Raphson techniques more applicable to transmission networks, the BFS method is able to actually ‘map’ the distribution system as a tree in essence with the slack bus as the root node and distant nodes as the leaves. The entire process of the methodology mainly involves the following steps:

1. Prepare the load and line data for the distribution system.

2. Assume initial voltages at all buses to be 1 per unit (p.u.).

3. During the backward sweep, calculate the real and reactive power flows using the following equations [39] :

$$P_i = P_j + P_{L_j} + R_{ij} \cdot \frac{\left(P_j'^2 + Q_j'^2\right)}{\left|V_j\right|^2}$$

(3.15)

$$Q_i = Q_j + Q_{L_j} + X_{ij} \cdot \frac{\left(P_j'^2 + Q_j'^2\right)}{\left|V_j\right|^2}$$

(3.16)

4. Update the voltages and phase angles using the forward sweep with these equations:

$$V_j = \left[V_i^2 - 2\left(P_i R_{ij} + Q_i X_{ij}\right) + \left(R_{ij}^2 + X_{ij}^2\right) \cdot \frac{\left(P_i^2 + Q_i^2\right)}{V_i^2}\right]^{1/2}$$

(3.17)

$$\theta_j = \theta_i + \tan^{-1}\left(\frac{Q_i R_{ij} - P_i X_{ij}}{V_i^2 - \left(P_i R_{ij} + Q_i X_{ij}\right)}\right)$$

(3.18)

5. Compute the power mismatch and check the termination criteria:

$$DeltaS_i^{(k)} = S_i^{sch} - V_i^{(k)}\left(I_i^{(k)}\right)^* \leq \epsilon \tag{3.19}$$

6. If the termination criteria are not met, repeat the process.

7. Once the termination criteria are satisfied, compute the branch power losses and total system losses using these equations [39]:

$$P_{loss}(i,j) = R_{ij} \cdot \frac{P_i^2 + Q_i^2}{|V_i|^2} \tag{3.20}$$

$$Q_{loss}(i,j) = X_{ij} \cdot \frac{P_i^2 + Q_i^2}{|V_i|^2} \tag{3.21}$$

3.3 User Manual for Operating Torrit with MATLAB:

3.3.1 Introduction

Welcome to the Power System Simulation Tool User Manual. This manual provides a comprehensive guide to installing, configuring, and using the software for load flow analysis and optimization of distributed generator (DG) placement. Whether you're a beginner or an advanced user, this manual will walk you through each step to ensure you can effectively utilize the tool.

3.3.2 System Requirements

Before you start, ensure your system meets the following requirements:

- **Operating System**: Windows
- **MATLAB**: Version 2018b or later recommended
- **MATPOWER**: Version 8.0b1
- **Hardware**: Sufficient disk space and memory to run MATLAB
- **Processor**: Minimum of dual-core, quad-core or higher recommended for large-scale simulations
- **RAM**: Minimum 4GB, 8GB or higher recommended for large network simulations

3.3.3 Installation

3.3.3.1 Installing MATLAB

1. **Download MATLAB**:
    - Visit the MATLAB official website and download the installer.

    - Ensure you have a valid license to activate the software.

2. **Install MATLAB**:
    - Run the downloaded installer.
    - Follow the on-screen instructions to complete the installation process.
    - Select the components you need based on your usage.
3. **Activate MATLAB**:
    - After installation, activate MATLAB using your MathWorks account.
    - Follow the activation instructions provided.

3.3.3.2 Installing MATPOWER

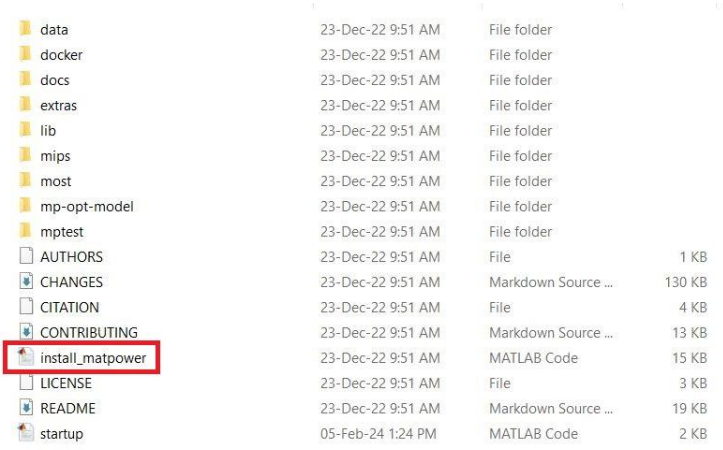
1. **Download MATPOWER**:
    - Go to [MATPOWER's website]() and download the latest version as a ZIP file.

Figure 2 Download from MATPOWER website

2. **Extract MATPOWER**:
    - Extract the ZIP file to a directory of your choice on your computer.
3. **Install MATPOWER**:
    - Open MATLAB or directory where you have extracted MATPOWER.

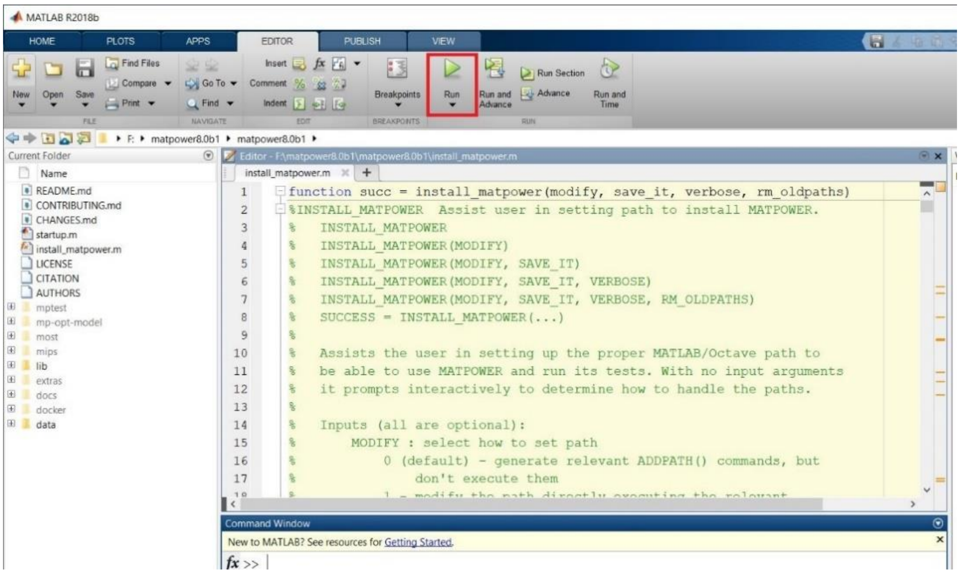
- Open install_matpower file from the extracted folder.

- Run install_matpower file in matlab.



data	23-Dec-22 9:51 AM	File folder	
docker	23-Dec-22 9:51 AM	File folder	
docs	23-Dec-22 9:51 AM	File folder	
extras	23-Dec-22 9:51 AM	File folder	
lib	23-Dec-22 9:51 AM	File folder	
mips	23-Dec-22 9:51 AM	File folder	
most	23-Dec-22 9:51 AM	File folder	
mp-opt-model	23-Dec-22 9:51 AM	File folder	
mptest	23-Dec-22 9:51 AM	File folder	
AUTHORS	23-Dec-22 9:51 AM	File	1 KB
CHANGES	23-Dec-22 9:51 AM	Markdown Source ...	130 KB
CITATION	23-Dec-22 9:51 AM	File	4 KB
CONTRIBUTING	23-Dec-22 9:51 AM	Markdown Source ...	13 KB
install_matpower	23-Dec-22 9:51 AM	MATLAB Code	15 KB
LICENSE	23-Dec-22 9:51 AM	File	3 KB
README	23-Dec-22 9:51 AM	Markdown Source ...	19 KB
startup	05-Feb-24 1:24 PM	MATLAB Code	2 KB

Figure 3 Extracted MATPOWER directory



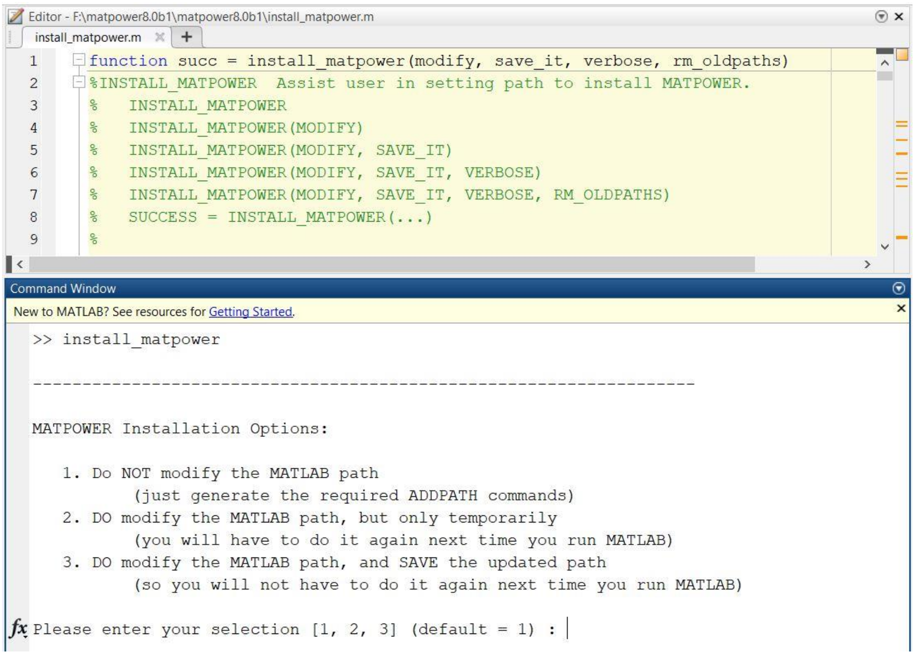
```
function succ = install_matpower(modify, save_it, verbose, rm_oldpaths)
%INSTALL_MATPOWER  Assist user in setting path to install MATPOWER.
%   INSTALL_MATPOWER
%   INSTALL_MATPOWER(MODIFY)
%   INSTALL_MATPOWER(MODIFY, SAVE_IT)
%   INSTALL_MATPOWER(MODIFY, SAVE_IT, VERBOSE)
%   INSTALL_MATPOWER(MODIFY, SAVE_IT, VERBOSE, RM_OLDPATHS)
%   SUCCESS = INSTALL_MATPOWER(...)
%
%   Assists the user in setting up the proper MATLAB/Octave path to
%   be able to use MATPOWER and run its tests. With no input arguments
%   it prompts interactively to determine how to handle the paths.
%
%   Inputs (all are optional):
%       MODIFY : select how to set path
%           0 (default) - generate relevant ADDPATH() commands, but
%               don't execute them
```

Figure 4 Run Install_MATPOWER

4. **Follow Installation Prompts**:

    - Choose option 3 to do modify the MATLAB path, and SAVE the updated path.

    - Select Y to run the MATPOWER tests to ensure everything is installed correctly.



```
function succ = install_matpower(modify, save_it, verbose, rm_oldpaths)
%INSTALL_MATPOWER  Assist user in setting path to install MATPOWER.
%   INSTALL_MATPOWER
%   INSTALL_MATPOWER(MODIFY)
%   INSTALL_MATPOWER(MODIFY, SAVE_IT)
%   INSTALL_MATPOWER(MODIFY, SAVE_IT, VERBOSE)
%   INSTALL_MATPOWER(MODIFY, SAVE_IT, VERBOSE, RM_OLDPATHS)
%   SUCCESS = INSTALL_MATPOWER(...)
%
```

```
>> install_matpower

-------------------------------------------------------------------

MATPOWER Installation Options:

   1. Do NOT modify the MATLAB path
          (just generate the required ADDPATH commands)
   2. DO modify the MATLAB path, but only temporarily
          (you will have to do it again next time you run MATLAB)
   3. DO modify the MATLAB path, and SAVE the updated path
          (so you will not have to do it again next time you run MATLAB)

Please enter your selection [1, 2, 3] (default = 1) :
```

Figure 5 MATPOWER Installation Options

3.3.4 Getting Started

3.3.4.1 Launching the Torrit Software

1. **Locate the Executable**:
    - Find the MATPOWER Case Building with Torrit.exe file on your computer.
2. **Open the Software**:
    - Double-click the executable file to launch the software.

3.3.4.2 Creating and Saving a Project

1. **Create a New Project**:
    - Go to the "File" menu and select "New Project."

- Enter a name for your project and click "OK."
- A new project workspace will open.

2. **Save Your Project**:

- Regularly save your work by selecting "Save Project" or "Save Project As" from the "File" menu.
- Choose a location on your computer to save the project file.

3.3.4.3 Configuring System Parameters

1. **Set System MVA**:

- Locate the "System MVA" field at the top right corner of the interface.
- Enter the total power capacity (in MVA) for your system.
- This value is critical for scaling the power flow calculations.

2. **Set Swing Bus**:

- Choose the swing bus, which serves as the reference point for voltage and phase angle calculations.
- The swing bus is typically the bus connected to the largest generator.

3.3.4.4 Placing and Editing Components

1. **Select and Place Components**:

- In the "Components" tab, select from generators, loads, buses, and transmission lines.
- Click on the workspace to place each component.
- Use the grid layout to ensure components are placed accurately.

2. **Connect Components**:

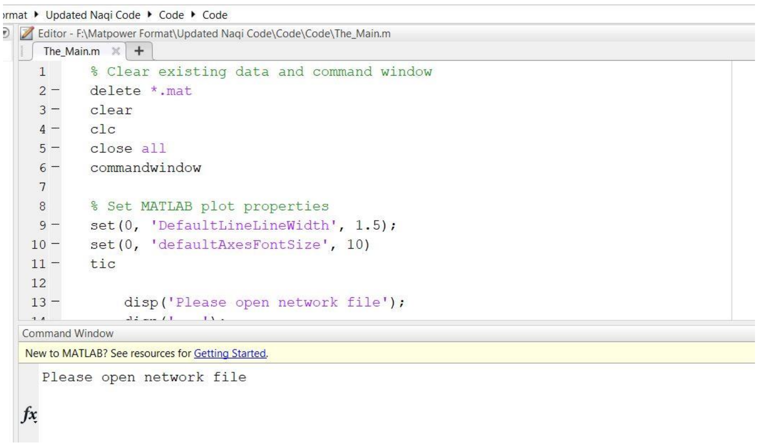
- Use the Transmission Line/Connector tool to connect components by clicking on the starting and ending points.
- Ensure all buses are properly connected to avoid errors in load flow analysis.

3. **Edit Component Properties**:
   - Double-click on any component to open its properties window.
   - Adjust parameters such as impedance, power rating, and load values as needed.
   - Click "OK" to save changes.
4. **Rotate and Drag Components**:
   - Rotate components by selecting them and pressing the "R" key.
   - Drag components by clicking and holding the mouse button, then moving them to the desired location.

3.3.5 Detailed Steps for MATLAB Code Burning

3.3.5.1 Open MATLAB Software

- Upon launching the software, it prompts you to open a network file designed in Torrit software.



```
% Clear existing data and command window
delete *.mat
clear
clc
close all
commandwindow

% Set MATLAB plot properties
set(0, 'DefaultLineLineWidth', 1.5);
set(0, 'defaultAxesFontSize', 10)
tic

    disp('Please open network file');
```

```
Please open network file
```

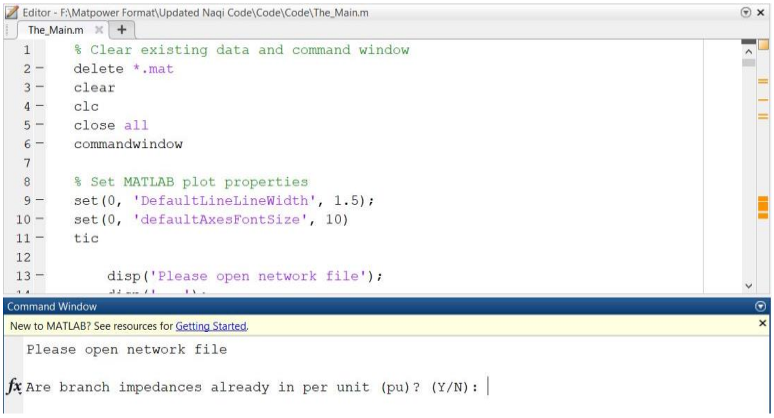
Figure 6 Open Network file

- Browse to the location of matpower file that is designed using torrit software and open it.
- The network data, including bus data, load data, branch data, and generator data, will be loaded into the workspace.

1. Input Prompts for Impedances and Loads

Impedances in Per Unit:

- The software asks if the branch impedances are in per unit (pu).



```
% Clear existing data and command window
delete *.mat
clear
clc
close all
commandwindow

% Set MATLAB plot properties
set(0, 'DefaultLineLineWidth', 1.5);
set(0, 'defaultAxesFontSize', 10)
tic

    disp('Please open network file');
```

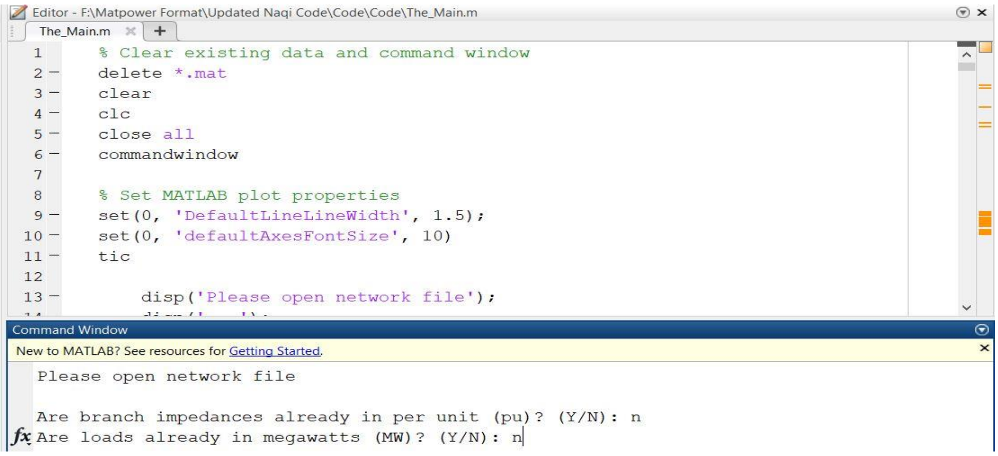
```
Please open network file

Are branch impedances already in per unit (pu)? (Y/N):
```

Figure 7 Are branch impedances already in per unit

- If the values are not in per unit, the software will automatically convert them.
- Ensure accurate entry to avoid calculation errors.

Loads in MW:

- The software asks if the load values are in MW.
- If the values are not in MW, the software will convert them accordingly.
- Accurate load data is essential for precise analysis.



```
% Clear existing data and command window
delete *.mat
clear
clc
close all
commandwindow

% Set MATLAB plot properties
set(0, 'DefaultLineLineWidth', 1.5);
set(0, 'defaultAxesFontSize', 10)
tic

    disp('Please open network file');
```

```
Please open network file

Are branch impedances already in per unit (pu)? (Y/N): n
Are loads already in megawatts (MW)? (Y/N): n
```

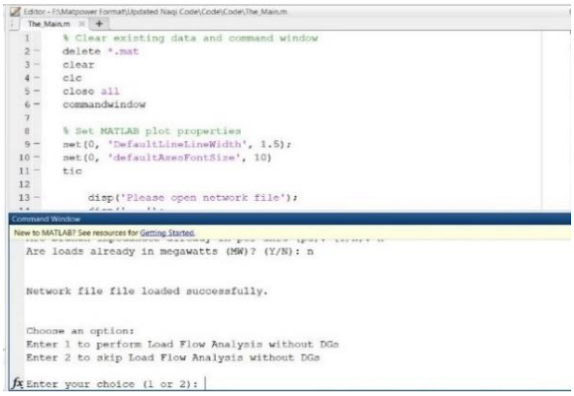
Figure 8 Are loads already in MW

Pro Tip: By default, the torrit software asks the user to enter the impedances and load data in per unit and MW respectively. However, if the user has entered the impedances actual values and loads in kW then the code is capable of making the conversions to per unit and MW.

3.3.5.2 User Choices

1. **Choose Analysis Option**:

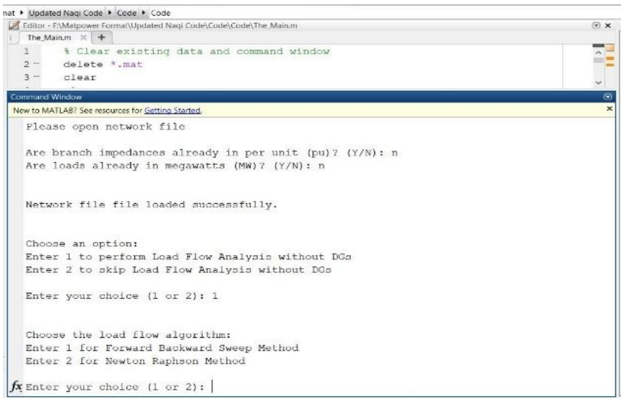
- When prompted, choose whether to perform load flow analysis without DGs.
    - Enter 1 to perform Load Flow Analysis without DGs
    - Enter 2 to skip Load Flow Analysis without DGs



```
% Clear existing data and command window
delete *.mat
clear
clc
close all
commandwindow

% Set MATLAB plot properties
set(0, 'DefaultLineLineWidth', 1.5);
set(0, 'defaultAxesFontSize', 10)
tic

    disp('Please open network file');
```

```
Are loads already in megawatts (MW)? (Y/N): n


Network file file loaded successfully.


Choose an option:
Enter 1 to perform Load Flow Analysis without DGs
Enter 2 to skip Load Flow Analysis without DGs

Enter your choice (1 or 2):
```

Figure 9 Choose an Option for Analysis



```
% Clear existing data and command window
delete *.mat
clear
```

```
Please open network file

Are branch impedances already in per unit (pu)? (Y/N): n
Are loads already in megawatts (MW)? (Y/N): n


Network file file loaded successfully.


Choose an option:
Enter 1 to perform Load Flow Analysis without DGs
Enter 2 to skip Load Flow Analysis without DGs

Enter your choice (1 or 2): 1


Choose the load flow algorithm:
Enter 1 for Forward Backward Sweep Method
Enter 2 for Newton Raphson Method

Enter your choice (1 or 2):
```

Figure 10 Choose Load Flow Algorithm

2. **Choose Load Flow Algorithm**:

- If the user selects 1 in the previous prompt, then in next step the code asks the user to select the algorithm to use for load flow analysis.
  - Enter 1 for Backward Forward Sweep Method
  - Enter 2 for Newton Raphson Method

3.3.6 Performing Load Flow Analysis

3.3.6.1 Without Distributed Generators (DGs)

1. **Run Analysis**:
   - Perform load flow analysis using the selected algorithm.
   - The software calculates power losses, voltage at buses, power flows, and power factor.
2. **Save Results**:
   - Results are saved in an Excel file and figures in .fig format.
   - Review the data to understand the current system performance.
3. **Review and Interpret Results**:
   - Examine the power losses, voltage profiles, and power flows.
   - Identify areas with significant losses or voltage deviations.

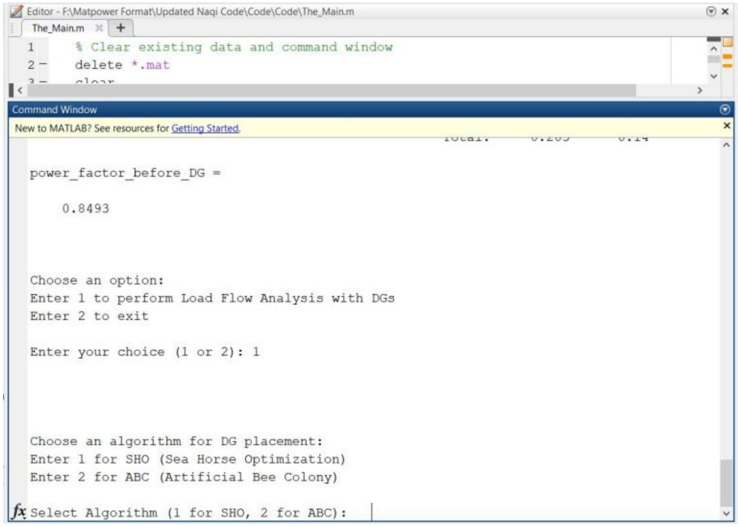
Pro Tip: Regularly check for voltage drops or rises at each bus to ensure they remain within acceptable limits.

3.3.6.2 With Distributed Generators (DGs)

1. **Choose Analysis Option**:

- After the initial load flow analysis, decide whether to perform analysis with DGs.

    - Enter 1 to perform Load Flow Analysis with DGs.
    - Enter 2 to exit.



```
% Clear existing data and command window
delete *.mat
```

```
power_factor_before_DG =

    0.8493



Choose an option:
Enter 1 to perform Load Flow Analysis with DGs
Enter 2 to exit

Enter your choice (1 or 2): 1




Choose an algorithm for DG placement:
Enter 1 for SHO (Sea Horse Optimization)
Enter 2 for ABC (Artificial Bee Colony)

fx Select Algorithm (1 for SHO, 2 for ABC):
```

Figure 11 Load Flow Analysis with DG or exit

2. **Select Optimization Algorithm**:

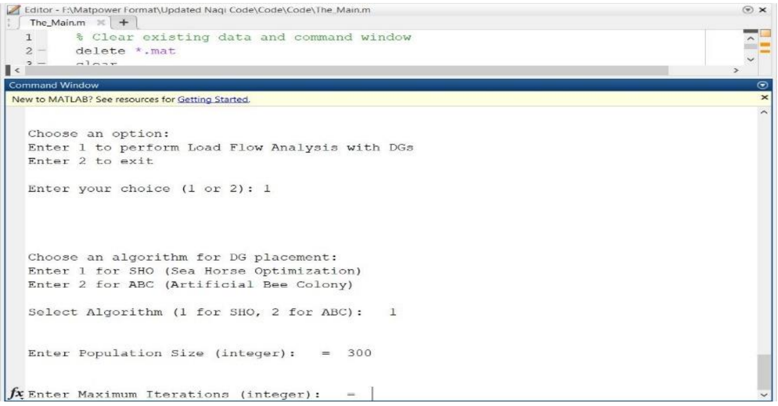
- Choose the algorithm for DG placement.
    - Enter 1 for SHO (Sea Horse Optimization)
    - Enter 2 for ABC (Artificial Bee Colony)

3. **Input Algorithm Parameters**:

To input the algorithm parameters for Distributed Generator (DG) placement, follow these detailed steps:

I. **Enter Population Size**:

    - A prompt will appear asking for the population size.
    - This is the number of candidate solutions the algorithm will generate and evaluate in each iteration.
    - **Example**: Enter 100 for a moderate-sized population.



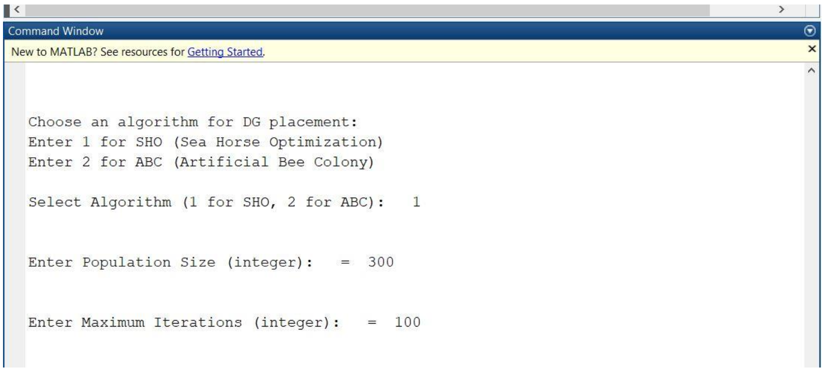
```
% Clear existing data and command window
delete *.mat
```

```
Choose an option:
Enter 1 to perform Load Flow Analysis with DGs
Enter 2 to exit

Enter your choice (1 or 2): 1



Choose an algorithm for DG placement:
Enter 1 for SHO (Sea Horse Optimization)
Enter 2 for ABC (Artificial Bee Colony)

Select Algorithm (1 for SHO, 2 for ABC):   1


Enter Population Size (integer):   =  300


Enter Maximum Iterations (integer):   =
```

Figure 12 Enter Population Size

II. **Specify Maximum Iterations**:

- Next, you will be asked to specify the maximum number of iterations.
- This determines how many times the algorithm will repeat its search process.
- **Example**: Enter 100 for a standard optimization run.



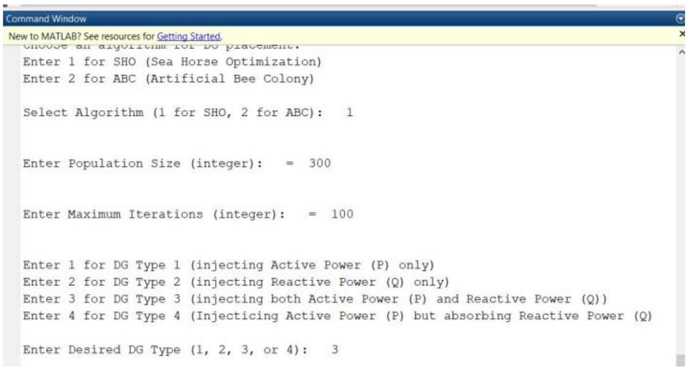
```
Choose an algorithm for DG placement:
Enter 1 for SHO (Sea Horse Optimization)
Enter 2 for ABC (Artificial Bee Colony)

Select Algorithm (1 for SHO, 2 for ABC):   1


Enter Population Size (integer):   =  300


Enter Maximum Iterations (integer):   =  100
```

Figure 13 Enter Maximum Iterations

III. **Select DG Type**:

- A prompt will ask you to choose the type of DG to place in the network.
- Enter 1 for DG type 1 injecting Active Power only, DG type 2 for injecting Reactive Power, 3 for injecting Active as well as Reactive Power, and 4 for injecting Active Power and absorbing Reactive Power.

- Typical types include renewable sources like solar and wind, capacitor banks or synchronous condenser type DG.
- **Example**: Enter 1 for Solar PV, 2 for Capacitor bank, 3 for synchronous condenser and 4 for Wind type DG.

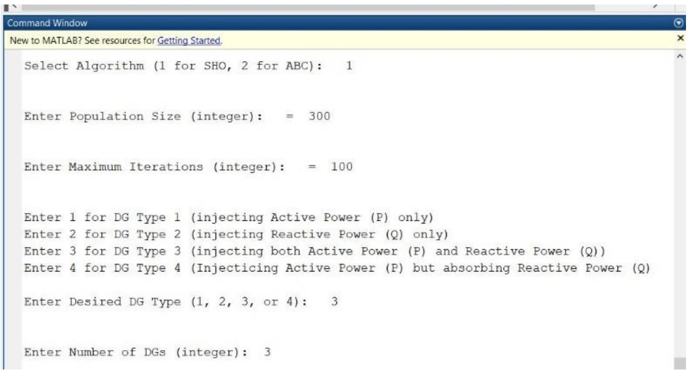


```
Choose an algorithm for DG placement:
Enter 1 for SHO (Sea Horse Optimization)
Enter 2 for ABC (Artificial Bee Colony)

Select Algorithm (1 for SHO, 2 for ABC):   1


Enter Population Size (integer):   =  300


Enter Maximum Iterations (integer):   =  100


Enter 1 for DG Type 1 (injecting Active Power (P) only)
Enter 2 for DG Type 2 (injecting Reactive Power (Q) only)
Enter 3 for DG Type 3 (injecting both Active Power (P) and Reactive Power (Q))
Enter 4 for DG Type 4 (Injecticing Active Power (P) but absorbing Reactive Power (Q)

Enter Desired DG Type (1, 2, 3, or 4):   3
```

Figure 14 Select DG type

IV. **Define Number of DGs**:

- Specify the total number of DG units to be placed in the network.
- This helps the algorithm know how many units to optimize for.
- **Example**: Enter 3 if you plan to place three DG units.



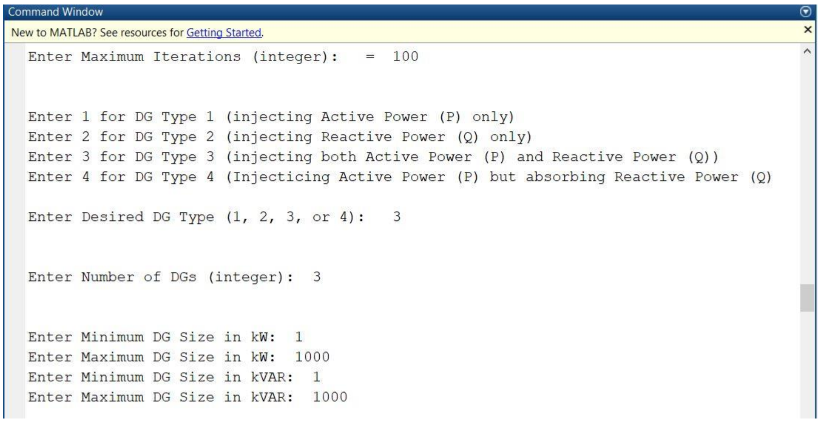
```
Select Algorithm (1 for SHO, 2 for ABC):   1


Enter Population Size (integer):   =  300


Enter Maximum Iterations (integer):   =  100


Enter 1 for DG Type 1 (injecting Active Power (P) only)
Enter 2 for DG Type 2 (injecting Reactive Power (Q) only)
Enter 3 for DG Type 3 (injecting both Active Power (P) and Reactive Power (Q))
Enter 4 for DG Type 4 (Injecticing Active Power (P) but absorbing Reactive Power (Q)

Enter Desired DG Type (1, 2, 3, or 4):   3


Enter Number of DGs (integer):  3
```

Figure 15 Enter Number of DGs

V. **Set DG Size Ranges**:

- Enter the size ranges for the DG units in terms of kW and kVAR.

    - This includes the minimum and maximum capacities for active and reactive power.
    - **Example**: For active power, enter 50 kW as the minimum and 200 kW as the maximum. For reactive power, enter 30 kVAR as the minimum and 100 kVAR as the maximum.



```
Enter Maximum Iterations (integer):   =  100


Enter 1 for DG Type 1 (injecting Active Power (P) only)
Enter 2 for DG Type 2 (injecting Reactive Power (Q) only)
Enter 3 for DG Type 3 (injecting both Active Power (P) and Reactive Power (Q))
Enter 4 for DG Type 4 (Injecticing Active Power (P) but absorbing Reactive Power (Q)

Enter Desired DG Type (1, 2, 3, or 4):   3


Enter Number of DGs (integer):  3


Enter Minimum DG Size in kW:  1
Enter Maximum DG Size in kW:  1000
Enter Minimum DG Size in kVAR:  1
Enter Maximum DG Size in kVAR:  1000
```

Figure 16 Enter DG size range

VI. **Run Optimization**:

- The algorithm optimizes DG placement based on the specified objective function.
- The software displays results and visualizes them using graphs.

VII. **Review and Save Results**:

- Analyze the optimized DG placements and their impact on the system.
- Save the results for future reference and comparison.

Pro Tip: Use optimization results to adjust the network design for improved performance.

3.3.7 Optimization Algorithms for DG Placement

3.3.7.1 Sea Horse Optimization Algorithm (SHO)

1. **Algorithm Overview**:

- SHO mimics the mating behavior of sea horses.
- Balances exploration (diversity of solutions) and exploitation (convergence to optimal solution).

2. **Algorithm Steps**:

- **Initialization**: Generate initial population of solutions.
- **Evaluation**: Assess each solution using the objective function.
- **Selection and Mating**: Select top-performing solutions for mating.
- **Update**: Generate new solutions by combining parents' characteristics.
- **Termination**: Repeat until maximum iterations or convergence criteria are met.
- **Parameters**:
- Population Size: Number of candidate solutions.
- Maximum Iterations: Number of generations for optimization.
- **Execution**:
- The algorithm iterates through candidate solutions, refining them to find the optimal placement of DGs.
- Results include the best DG locations and their impact on the system.

Pro Tip: SHO is effective in balancing the search process, making it suitable for complex optimization problems.

3.3.7.2 Artificial Bee Colony Algorithm (ABC)

1. **Algorithm Overview**:

- ABC simulates the foraging behavior of honeybees.
- Known for efficient exploration of the solution space.

2. **Algorithm Steps**:

- **Initialization**: Generate initial population of solutions.
- **Employed Bees Phase**: Each bee modifies its solution based on local information.
- **Onlooker Bees Phase**: Bees choose solutions based on a probability related to their quality.
- **Scout Bees Phase**: Replace abandoned solutions with new random solutions.
- **Termination**: Repeat until maximum iterations or convergence criteria are met.

Parameters:

- Population Size: Number of bees (candidate solutions).
- Maximum Iterations: Number of generations for the algorithm.

Execution:

- The algorithm evaluates candidate solutions and refines them to identify optimal DG placements.
- Outputs include the best DG locations and their impact on system performance.

Pro Tip: ABC is excellent for avoiding local minima and exploring diverse solutions, making it ideal for DG placement.

3.3.8 Load Flow and Optimization Results

3.3.8.1 Load Flow Analysis Results

1. **Voltage at Buses**:
    - Displays voltage levels at each bus.
    - Identifies any buses with voltage deviations from nominal values.

Table 1 Voltage at buses

Bus Number	**Voltage (P.u)**
1	1
2	0.99703226
3	0.982937983
4	0.975456413
5	0.968059232
6	0.949658177
7	0.946172614
8	0.941328437
9	0.935059372
10	0.929244423
11	0.928384417
12	0.926884837
13	0.920771748
14	0.918504993
15	0.91709268
16	0.91572476
17	0.913697546
18	0.913090479
19	0.996503896
20	0.9929263
21	0.992221796
22	0.991584377
23	0.979352257
24	0.972681101
25	0.969356112
26	0.94772891
27	0.945165164
28	0.933725581
29	0.925507478
30	0.921950058
31	0.917788887
32	0.916873466
33	0.916589822

2. **Average Voltage**:
    - Shows the average voltage across the system.
    - Helps assess overall system voltage stability.
3. **Active Power Loss**:
    - Details power losses at each iteration and between branches.
    - Helps identify areas with significant power loss.

Table 2 Active Power Loss at branches

From Branch	To Branch	APL(kw)
1	2	6.239695649
2	3	26.37886194
3	4	10.13510604
4	5	9.523654326
5	6	33.01804265
6	7	6.32854428
7	8	1.598827083
8	9	3.003492598
9	10	2.524019638
10	11	0.183065222
11	12	0.291358035
12	13	2.09775361
13	14	0.959784732
14	15	0.317712893
15	16	0.205546455
16	17	0.335967627
17	18	0.04166665
18	19	0.153593488
19	20	0.749855262
20	21	0.117711008
21	22	0.057693062
22	23	2.173972168
23	24	4.061670613
24	25	1.007402689
25	26	1.324791602
26	27	1.694952169
27	28	9.963748379
28	29	6.824229017
29	30	1.984296279
30	31	1.574993316
31	32	0.248487415
32	33	0.020475079

4. **Reactive Power Loss**:

- Lists reactive power losses at each iteration and between branches.
- Important for understanding reactive power distribution.

Table 3 Reactive Power Loss at branches

From Branch	**To Branch**	**RPL(kVAR)**
1	2	12.24042423
2	3	51.79123431
3	4	19.90047645
4	5	18.69894211
5	6	38.24862367
6	7	1.914517597
7	8	4.837965066
8	9	4.180536994
9	10	3.560914193
10	11	0.553701887
11	12	0.881134477
12	13	2.666235757
13	14	0.729161749
14	15	0.356973992
15	16	0.28146664
16	17	0.251634091
17	18	0.053135867
18	19	0.160954198
19	20	0.832176689
20	21	0.100758064
21	22	0.043634494
22	23	3.18162907
23	24	5.143675379
24	25	1.287452303
25	26	2.600896472
26	27	3.328993824
27	28	11.30085631
28	29	7.833349951
29	30	3.895668709
30	31	1.593638097
31	32	0.213195199
32	33	0.01316862

Review Excel Files:

- Load flow results are saved in Excel files.
- Review power losses, voltage profiles, power flows, and power factors.

Review Figures:

- Load flow analysis figures are saved in .fig format.
- Visualize voltage profiles, power flows, and other key parameters.

Pro Tip: Use Excel's data analysis tools to gain deeper insights into the results.

3.3.8.2 Optimization Results

1. **Convergence Curve**:
    - Shows the MOI of the optimization algorithm over iterations.
    - Helps assess the efficiency and stability of the optimization process.

Table 4 MOI with Iterations

Iteration #	**MOI**
1	0.115074
2	0.115074
3	0.115074
4	0.115074
5	0.115074
6	0.112861
7	0.112861
8	0.112861
9	0.112861
10	0.112861
11	0.112861
12	0.112861
13	0.112861
14	0.112861
15	0.112861
16	0.112861
17	0.112861
18	0.112861
19	0.112861
20	0.112861
21	0.112861
22	0.112861
23	0.112861

24	0.112861
25	0.112861
26	0.112861
27	0.112861
28	0.112861
29	0.112861
30	0.112861
31	0.112861
32	0.112861
33	0.112861
34	0.112861
35	0.112861
36	0.112861
37	0.112861
38	0.112861
39	0.112861
40	0.112861
41	0.112861
42	0.112861
43	0.112861
44	0.112861
45	0.112861
46	0.112861
47	0.112861
48	0.112861
49	0.112861
50	0.112861
51	0.112861
52	0.112861
53	0.112861
54	0.112861
55	0.112861
56	0.112861
57	0.112861
58	0.112861
59	0.112861
60	0.112861
61	0.112861
62	0.112861
63	0.112861
64	0.112861
65	0.112861
66	0.112861
67	0.112861
68	0.112861
69	0.112861
70	0.112861
71	0.112861
72	0.112861
73	0.112861
74	0.112861
75	0.112861
76	0.112861
77	0.112861
78	0.112861
79	0.099889
80	0.099889
81	0.09882
82	0.091721
83	0.091156
84	0.081343
85	0.080586
86	0.079696

87	0.079109
88	0.079089
89	0.079089
90	0.079089
91	0.079089
92	0.079089
93	0.079089
94	0.079089
95	0.079056
96	0.079056
97	0.078855
98	0.078355
99	0.07092
100	0.070631

2. **Voltage Profiles**:

    - Displays voltage levels at buses before and after DG placement.
    - Helps in evaluating the impact of DGs on voltage stability.

Table 5 Voltage at buses with DGs

Bus Number	**Voltage (P.u)**
1	1
2	0.999435
3	0.998179
4	0.997312
5	0.996792
6	0.996111
7	0.996487
8	0.996842
9	0.999759
10	1.003179
11	1.003728
12	1.004902
13	0.999274
14	0.997188
15	0.995888
16	0.994629
17	0.992763
18	0.992204
19	0.998907
20	0.995339
21	0.994636
22	0.994
23	0.998665
24	1.000673
25	0.997441
26	0.996179

27	0.996403
28	0.997569
29	0.998849
30	1.000199
31	0.996366
32	0.995523
33	0.995262

3. **Power Losses with DGs**:

- Details active and reactive power losses with DGs.
- Important for understanding the benefits of DG placement in reducing losses.
- Details power losses between branches.

Table 6 Voltage at busses with DG

From Branch	**To Branch**	**APL(kw)**	**RPL(kw)**
1	2	0.671371652	0.342239346
2	3	1.591098075	0.810394983
3	4	0.275727019	0.140424908
4	5	0.112057715	0.057072691
5	6	0.12954616	0.111830446
6	7	0.080017983	0.264503887
7	8	0.301356777	0.099590917
8	9	1.080001272	0.775923244
9	10	1.367258625	0.969129677
10	11	0.318453309	0.105287208
11	12	0.735195983	0.243101663

12	13	2.260583585	1.778592671
13	14	0.618090358	0.813583117
14	15	0.302480427	0.269212698
15	16	0.238444438	0.174128659
16	17	0.21312274	0.284549446
17	18	0.045000056	0.035286929
18	19	0.160175578	0.152850476
19	20	0.828142456	0.746220107
20	21	0.100269274	0.117139977
21	22	0.043422683	0.057413007
22	23	0.826238596	0.56455975
23	24	1.812719909	1.43140277
24	25	1.215971165	0.951470295
25	26	0.031513729	0.016051821
26	27	0.065284383	0.033239445
27	28	0.378396391	0.333624844
28	29	0.434623949	0.378634094
29	30	0.538880807	0.274484116
30	31	1.351906809	1.336090166
31	32	0.180835785	0.210771242
32	33	0.011169033	0.017366044

- Details power losses at each iteration.

Table 7 Total Active and Reactive Power Loss with respect to iterations

Iteration #	APL per Iteration (kw)	RPL per Iteration (kVAR)
1	24.30311051	33.49034219
2	24.30311051	33.49034219
3	24.30311051	33.49034219
4	24.30311051	33.49034219
5	24.30311051	33.49034219
6	21.75307797	30.9002244
7	21.75307797	30.9002244
8	21.75307797	30.9002244
9	21.75307797	30.9002244
10	21.75307797	30.9002244
11	21.75307797	30.9002244
12	21.75307797	30.9002244
13	21.75307797	30.9002244
14	21.75307797	30.9002244
15	21.75307797	30.9002244
16	21.75307797	30.9002244
17	21.75307797	30.9002244
18	21.75307797	30.9002244
19	21.75307797	30.9002244
20	21.75307797	30.9002244
21	21.75307797	30.9002244
22	21.75307797	30.9002244
23	21.75307797	30.9002244

24	21.75307797	30.9002244
25	21.75307797	30.9002244
26	21.75307797	30.9002244
27	21.75307797	30.9002244
28	21.75307797	30.9002244
29	21.75307797	30.9002244
30	21.75307797	30.9002244
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32	21.75307797	30.9002244
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35	21.75307797	30.9002244
36	21.75307797	30.9002244
37	21.75307797	30.9002244
38	21.75307797	30.9002244
39	21.75307797	30.9002244
40	21.75307797	30.9002244
41	21.75307797	30.9002244
42	21.75307797	30.9002244
43	21.75307797	30.9002244
44	21.75307797	30.9002244
45	21.75307797	30.9002244
46	21.75307797	30.9002244
47	21.75307797	30.9002244

48	21.75307797	30.9002244
49	21.75307797	30.9002244
50	21.75307797	30.9002244
51	21.75307797	30.9002244
52	21.75307797	30.9002244
53	21.75307797	30.9002244
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67	21.75307797	30.9002244
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70	21.75307797	30.9002244
71	21.75307797	30.9002244

72	21.75307797	30.9002244
73	21.75307797	30.9002244
74	21.75307797	30.9002244
75	21.75307797	30.9002244
76	21.75307797	30.9002244
77	21.75307797	30.9002244
78	21.75307797	30.9002244
79	22.52625779	32.43456572
80	22.52625779	32.43456572
81	21.490311	30.99351528
82	18.7368869	26.81817771
83	18.12112682	25.97243174

84	15.16434013	20.77764238
85	14.87881646	20.39118009
86	14.67437231	20.16923048
87	14.26645435	19.6368607
88	14.18563158	19.56741876
89	14.18563158	19.56741876
90	14.18563158	19.56741876
91	14.18563158	19.56741876
92	14.18563158	19.56741876
93	14.18563158	19.56741876
94	14.18563158	19.56741876
95	14.18478676	19.57648888

96	14.18478676	19.57648888
97	14.15704301	19.55771203
98	14.20570972	19.53005709
99	12.72877599	16.66474005
100	13.89617064	18.31935672

Review Excel Files:

- Optimization results are saved in Excel files.
- Review DG placements, power losses, and voltage profiles.

Review Figures:

- Optimization figures are saved in .fig format.
- Visualize the impact of DG placements on the system.

Pro Tip: Compare pre- and post-optimization results to assess the effectiveness of DG placements.

3.3.9 Visualizing Results with Figures and Graphs

3.3.9.1 Load Flow Analysis Parameters

1. **Average Voltage**:
    - Shows the average voltage level across the system as shown in fig 22.
    - Useful for assessing overall system health.
2. **Active Power Loss**:
    - Plots active power losses at each iteration and between branches as shown in fig 24.

- Important for identifying areas with high losses.

3. **Reactive Power Loss**:
    - Plots reactive power losses at each iteration and between branches as shown in fig 25.
    - Helps in understanding reactive power distribution.
4. **Voltage at Buses**:
    - Graphically represents voltage levels at each bus as shown in fig 23.
    - Helps in visualizing voltage stability and identifying problematic areas.

3.3.9.2 Optimization Graphs

1. **Average Voltage**:
    - Shows the average voltage level across the system as shown in fig 22.
    - Useful for assessing overall system health.
2. **Voltage with DGs**:
    - Shows voltage levels at buses with DG placement as shown in fig 25.
    - Helps in evaluating the impact of DGs on voltage stability.

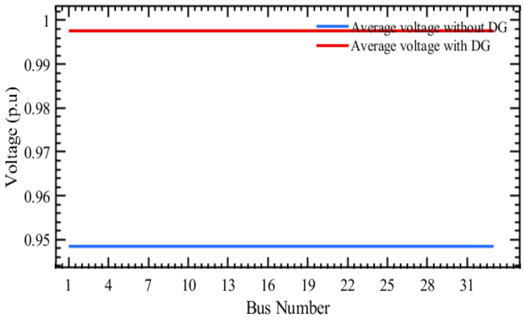

Figure 17 Average Voltage Comparison without and with DGs Graph

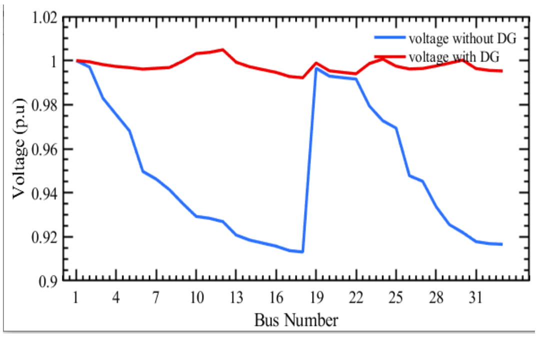

Figure 18 Voltage Comparison without and with DGs Graph

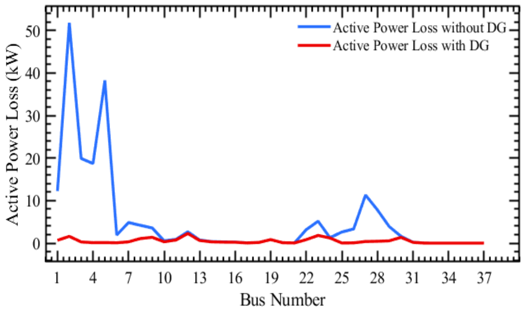

Figure 19 Comparison of Active Power Loss without and with DGs

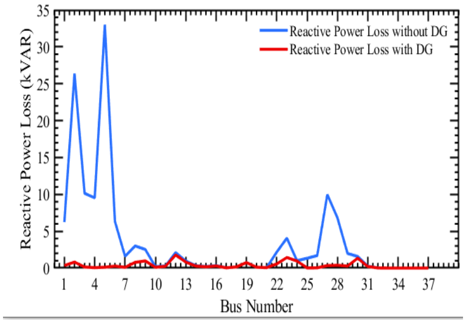

Figure 20 Reactive Power Loss Comparison without and with DGs

3. **Active Power Loss with DGs**:
    - Plots active power losses with DGs as shown in fig 24.
    - Important for understanding the benefits of DG placement in reducing losses.
4. **Reactive Power Loss with DGs**:
    - Plots reactive power losses with DGs as shown in fig 25s.
    - Helps in understanding the benefits of DG placement in managing reactive power.

3.3.9.3 Saving and Viewing Figures:

- Figures are saved in .fig format for later review in MATLAB.
- Use MATLAB's plotting tools to customize and analyze the figures.

Pro Tip: Regularly save graphical results to track performance changes over time and across different scenarios.

3.3.10 Example Scenarios

Scenario 1: Simple Load Flow Analysis

1. **Load a Network File**:

    - Open the network file designed in Torrit software.

2. **Perform Load Flow Analysis**:
    - Select the load flow algorithm (Backward Forward Sweep or Newton Raphson).
    - Run the analysis and review the results.
3. **Save Results**:
    - The results will be saved in Excel file and figures in .fig format for later review.

Scenario 2: DG Placement Optimization

1. **Load a Network File**:
    - Open the network file designed in Torrit software.
2. **Perform Initial Load Flow Analysis**:
    - Conduct analysis without DGs to establish a baseline.
3. **Select Optimization Algorithm**:
    - Choose SHO or ABC for DG placement.
4. **Input Parameters and Run Optimization**:
    - Enter population size, maximum iterations, DG type, and size ranges.
    - Run the optimization and review the results.
5. **Analyze and Save Results**:
    - Examine voltage profiles, power losses, and DG placements.
    - Save the optimization results and graphs.

Chapter 4

Proposed Algorithm

4 PROPOSED ALGORITHM

4.1 Sea Horse Optimization (SHO) Algorithm

The Sea Horse Optimization (SHO) algorithm is a nature-inspired metaheuristic that draws inspiration from the foraging behaviour of sea horses, which exhibit unique swimming patterns, hunting strategies, and interactions with their environment. This behaviour has been abstracted into an optimization technique that effectively balances exploration (searching for new solutions) and exploitation (refining known solutions). It is especially beneficial when solving such combined optimization problems as placement of Distributed Generation units in power distribution networks, intending DG units distribution in the way that will maximize the power factor.

Furthermore, the location of DG units significantly defines the extent of improvement of the overall efficiency of the distribution network. Regarding specific performances, lower losses, higher power factor as well as appropriate voltage levels can be achieved with a well-sited DG, resulting in a better network response. To this end, the SHO algorithm is optimized to apply an objective function may include loss reduction, improvement of the power factor or both. They called the set of potential solutions ‘Sea horses ‘ in SHO algorithm where each sea horse refers to a particular placement of DGs. In this case, the position of each sea horse in the search space corresponds to correspondent DG locations and sizes, which provides the basis for feedback phase to cover a wide variety of effective solutions. This exploration avoids the algorithm from being stuck in local optima, and indeed leads to optimality [41].

The proposed SHO algorithm uses the movement of sea horses as a base for its movements. For example, the hunting movement corresponds to sea horses moving toward areas with better solutions that could be achieved through refining the areas of DG placements featured in the improvement of the power factor. Also, the forming of swarms, so sea horses gather together, provides the directed motion in the direction of the areas with better solutions in order to turn into good ones. It also provides provisions for getting out of local optima which is similar to sea horse movement to escape predators and thus is able to keep on preserving the variety of search space and avoid the convergence problem.

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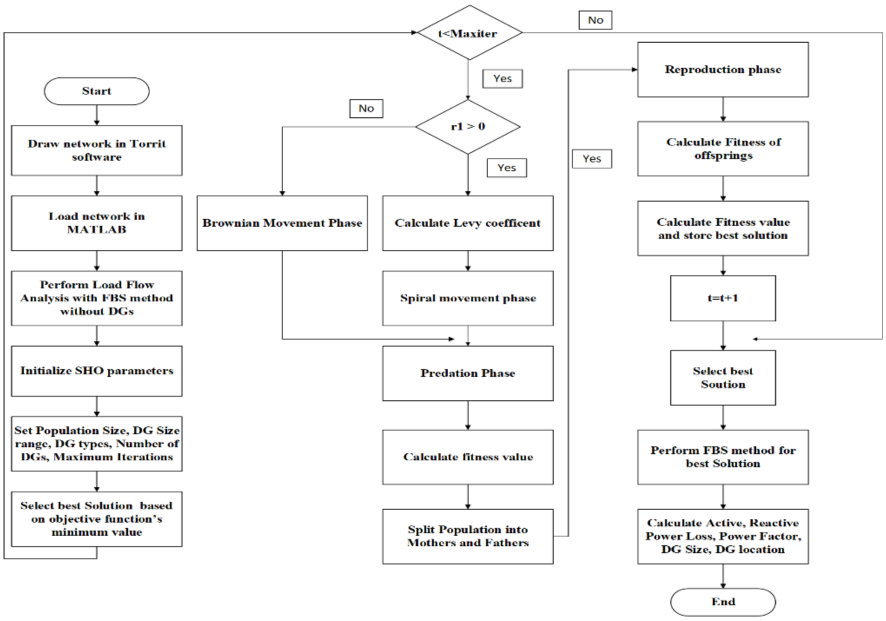


Figure 21 Flow Chart of SHO Algorithm

At the end of each iteration, the solutions are assessed against the objective function in order with regards to, for instance, the power factor improvement, loss reduction and voltage profile. Usually, the solutions that have had high performance ratings are maintained for the next iteration while others that had low ratings get eliminated or amended. This process is done until a certain stopping criterion is reached which may be certain number of iterations or a convergence criterion or a certain acceptable value of the power factor.

The major advantage of the SHO algorithm is in its use of exploration and exploitation, which makes SHO superior in searching for the global optimum not being stacked at the local one. Besides, its flexibility making it possible to fit the solution into different problem constraints and goals to solve, which makes it ideal in solving complicated, multiple objectives problems like determining the best placement of DGs. The algorithm is also lightweight, and this is desirable since power distribution networks can be extensive, and hence require efficient algorithms. However, many factors influence the run time and quality of the SHO Algorithm including the number of sea horses, maximum iteration point and the specific staking movements. Furthermore, there is the need to successfully incorporate it with accurate models of the power distribution network for an efficient evaluation of the objective function. To learn more about the proposition of SHO for DG placement, heed has to be paid on comparing it with existing optimisation algorithms like PSO, GA, or ACO. Summing up, the Sea Horse Optimization can be viewed as a new and promising heuristic algorithm for designing the DG placement relating to the power factor improvement, as its tendency to combine the global and local search methods give us a hope to reach the optimal solution [43].

Step 1: Start setting requirements for a model that has to be optimized with the help of SHO such as number of sea horses (solutions) , maximum number of iterations and regulating parameters such as exploration and exploitation.

Step 2: Produce the first set of sea horses where each one of them is a candidate solution of DG placement in the distribution network. Each position may be represented as a vector Xi where $i=1,2,\ldots,Ni = 1,2,\ldots,N$ (with N being the total number of sea horses)

Step 3: Calculate the fitness of each sea horse based on the objective function, such as minimizing losses or improving the power factor:

$$Fitness = f(Xi) \tag{4.1}$$

Step 4: Update the position of each sea horse using movement strategies like hunting and swarming. A typical position update might be [42]:

$$Xinew = Xi + r \times (Xbest - Xi) \tag{4.2}$$

where r is a random factor, and $\boldsymbol{Xbest}$ is the best position found so far.

Step 5: Recalculate the fitness for the updated positions. If $\boldsymbol{f(Xinew)}$ is better than the previous fitness, update the sea horse’s position.

Step 6: If diversity decreases or local optima are detected, introduce random perturbations to allow sea horses to escape local minima:

$$Xiescape = Xi + rand \times (Xmax - Xmin) \tag{4.3}$$

Step 7: Store the best solution found in the memory, then increment the iteration counter and repeat the process until the stopping criterion (e.g., maximum iterations) is met.

Step 8: Output the best solution for DG placement in the distribution network, which optimizes the power factor or other desired performance metrics.

4.1.1 Sea Horses Mobility Patterns

The movement of sea horses follows a normal distribution. It is divided into exploration and exploitation phases. In the exploitation phase, sea horses attempt to move towards the best sea horse represented by X_{elite}. The distance covered is represented by Levy flight [17], as described in (4.4).

$$X_{new}^{1}(t+1) = X_i(t) + Levy(\lambda)(X_{elite}(t) - X_i(t)) \times x \times y \times z + X_{elite}(t) \qquad (4.4)$$

The coordinates of sea horses are denoted by x, y, z, and the equation for Levy flight is given by (4.5).

$$Levy(z) = s \times \frac{w \times \sigma}{|k|^{\frac{1}{\lambda}}} \qquad (4.5)$$

Parameters w and k have values in the range of 0 to 1, λ is in the range of [0,2], s has a value of 0.01, and σ is determined by (4.6).

$$\sigma = \left(\frac{\Gamma(1+\lambda) \times \sin\left(\frac{\pi\lambda}{2}\right)}{\Gamma\left(\frac{1+\lambda}{2}\right) \times \lambda \times 2^{\left(\frac{\lambda-1}{2}\right)}} \right) \qquad (4.6)$$

Exploration is carried out using Brownian movement, where sea horses attempt to capture food by moving in a random direction, as given by (4.7).

$$X_{new}^{1}(t+1) = X_i(t) + rand \times l \times \beta_t \times (X_i(t) - \beta_t \times X_{elite}) \qquad (4.7)$$

The variable l is fixed, and β is a random walk variable determined by (4.8).

$$\beta = \frac{1}{\sqrt{2\pi}} \times e^{\left(\frac{-x^2}{2}\right)} \qquad (4.8)$$

4.1.2 Predation Behavior Phase

In the predation behavior phase, the hunting phase is divided into two scenarios based on the probability of success and failure, denoted by 1 and 0, respectively. In the exploitation phase, it is assumed that sea horses catch their prey with a 0.90 probability, while the exploration phase has a 0.10 probability. If a sea horse captures its prey, it out-ranks its opponent, becoming the elite soldier; otherwise, it explores other ways to capture prey. This phase is represented by (4.9).

$$X_{new}^{2}(t+1)=\begin{cases}\alpha\times(X_{elite}-rand\times X_{new}^{1}(t))+(1-\alpha)\times X_{elite} if r_2>0.1\\(1-\alpha)\times(X_{new}^{1}(t)-rand\times X_{elite})+\alpha\times X_{new}^{1}(t)\ if r_2\leq 0.1\end{cases}\tag{4.9}$$

X_{new}^{1} represents the new location of sea horses. r2 ranges between 0 and 1, and alpha is determined by (4.10).

$$\alpha=\left(1-\frac{t}{T}\right)^{\frac{2t}{T}}\tag{4.10}$$

T indicates the maximum iteration limit. Alpha can be changed to make the algorithm converge to its solution.

4.1.3 Reproduction phase of Sea horses

During the reproduction phase, the population is divided into two halves, with one half containing male sea horses and the other half containing female sea horses. This is given by (4.11).

$$X_i^{offspring}=r_3X_i^{father}+(1-r_3)X_i^{mother}\tag{4.11}$$

where r_3 is any number between 0 and 1.

Chapter 5

Results and Discussions

5 RESULTS AND DISCUSSIONS

Firstly, every network's required data was collected, including load profiles, voltage levels, line impedances, and the locations of any installed Distributed Generators (DGs). The ensuing analysis and optimization process need this baseline data. Following data collection, Torrit visualization was employed to offer a more complete image of each network's current state. By using this visualization technique, the inefficient or unbalanced areas of the network could be quickly identified, and determining the optimal locations for DG deployment was also made easier. Important components including load distribution, voltage stability, and power factor changes were all clearly depicted in each network's display.

After that, the experiment's findings are examined, paying close attention to how achieving the optimal power factor through strategic distributed generator (DG) placement impacts the network's overall performance. While several different DG types were employed, DG Type 3 was specifically used to obtain the results shown here. This choice was made because of its outstanding performance in power factor correction, voltage profile augmentation, and overall network efficiency. When it comes to achieving optimal performance, DG Type 3 performs better than other DG types due to its ability to effectively reduce power losses, boost voltage stability, and improve network efficiency [39]. In order to demonstrate the gains in power factor, voltage profiles, and overall network efficiency, this section presents a comparison between the initial state of the network and its optimized results.

The network characteristics that the IESCO Gujjar Khan Division uses to test and investigate the ideal power factor of distribution networks depending on the location of DG are described in detail. The efficiency of the used optimization techniques is demonstrated by the MATLAB results for each network, which also provide a quantitative analysis of the performance gains and highlight the noteworthy advantages of DG deployment strategy. .

To find the ideal distribution of DGs, two optimization methods were applied in addition to the load flow analysis. The study's main focus, the Sea Horse Optimization (SHO) approach, was used to determine the network's ideal DG layout. The identical task was also finished with the Artificial Bee Colony (ABC) method for comparison's sake. To assess how well each load flow strategy enhanced the distribution network's overall performance, these two algorithms were combined with it.

Following are the detailed analysis of optimization implemented on each network:

5.1 IEEE 33 Bus Network System:

A benchmark radial distribution network, the IEEE 33-bus system has 33 buses, 32 branches, a 3.72 MW total load, and 2.3 MVAR. It is frequently employed to evaluate optimization strategies for distributed generation integration, voltage stability, and power flow.

Here is the Torrit network single line diagram:

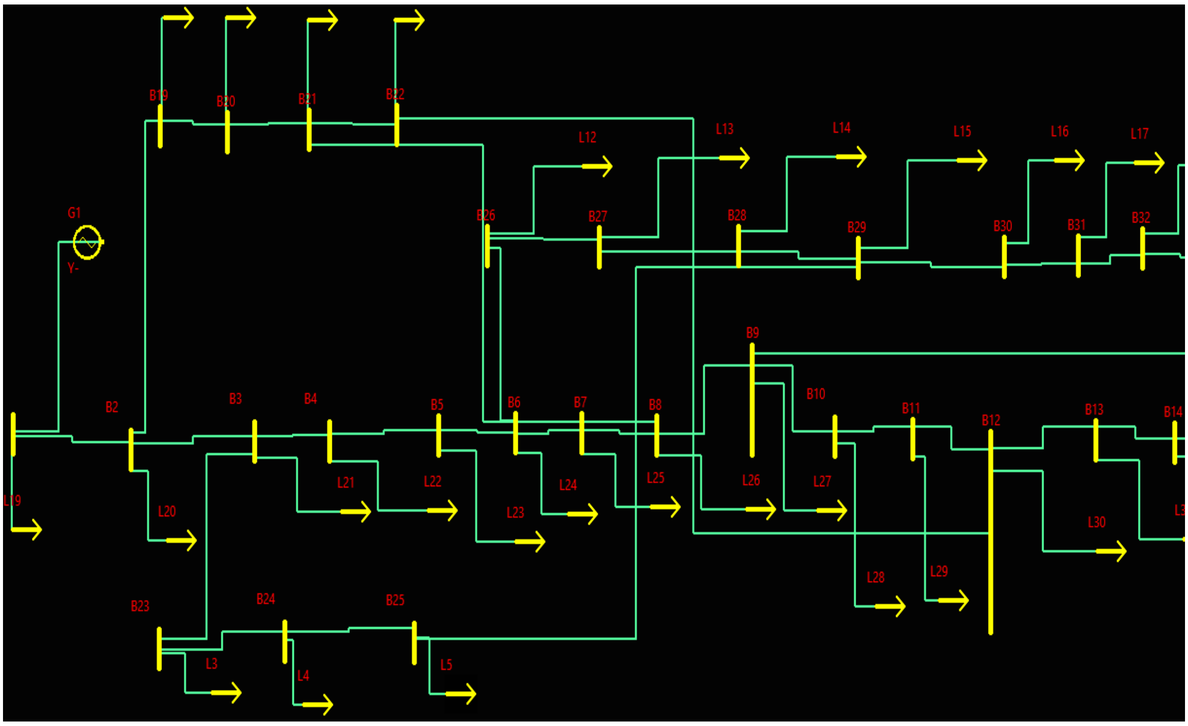


Figure 22 Torrit View of IEEE 33 Bus Network System

5.1.1 Backward Forward Sweep (BFS) Analysis of Network Using SHO Algorithm:

Below is the analysis of main parameters obtained using BFS method with SHO Algorithm:

5.1.1.1 Active Power Loss (APL) in term of DG placement:

Here is the graphical representation of Active Power Loss (APL) showing before and after placement of DGs optimally for Power factor improvement using BFS Method with SHO Algorithm:

5.1.1.2 Reactive Power Loss (RPL) in term of DG placement:

Here is the graphical representation of Reactive Power Loss (RPL) showing before and after placement of DGs optimally for Power factor improvement using BFS Method with SHO Algorithm:

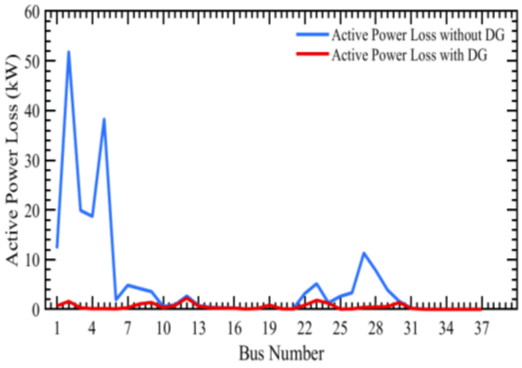


Figure 23 Active Power Loss (APL) in term of DG placement

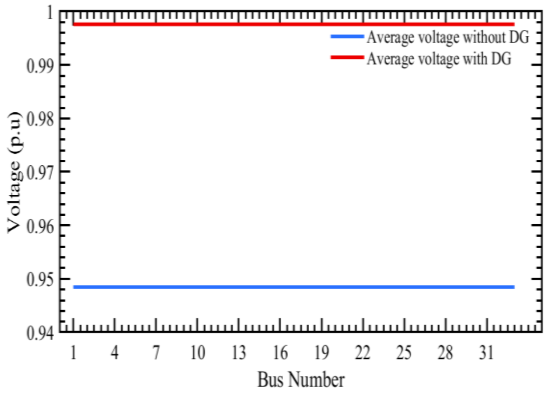


Figure 25 Average Voltage (Vavg) showing before and after placement of DGs

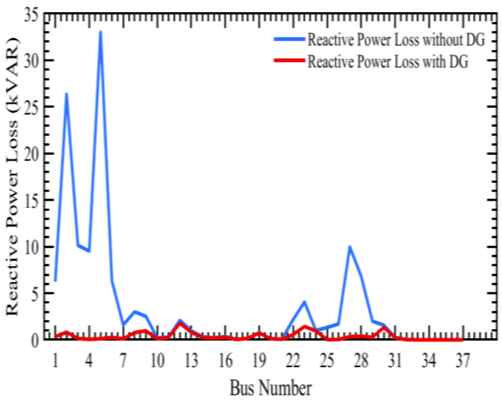


Figure 24 Reactive Power Loss (RPL) in term of DG placement:

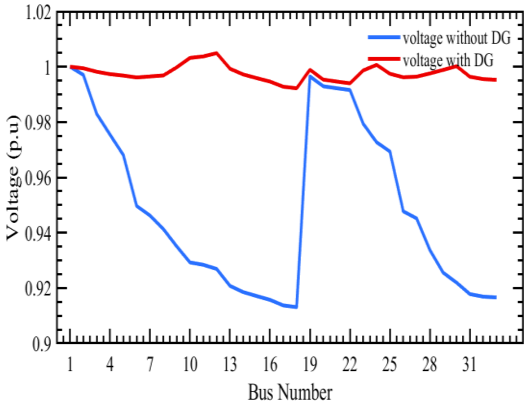


Figure 26 Minimum Voltage (Vmin) showing before and after placement of DGs

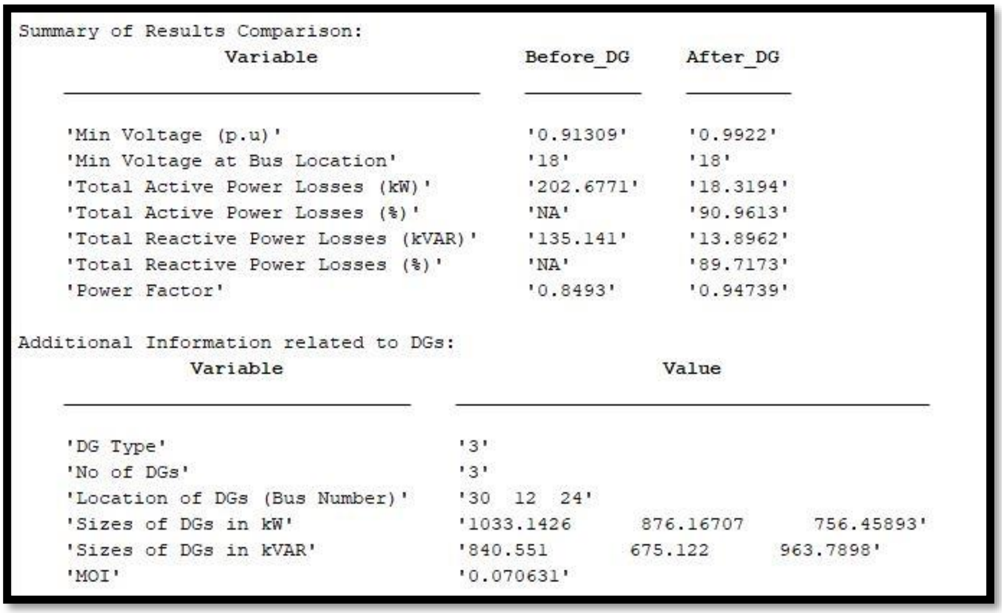
5.1.1.3 Minimum Voltage (V_{min}) in term of DG placement:

Here is the graphical representation of Minimum Voltage (V_{min}) showing before and after placement of DGs optimally for Power factor improvement using BFS Method with SHO Algorithm.:

5.1.1.4 Results Summary Using SHO Algorithm:

The SHO algorithm's results summary emphasizes the Distributed Generators' (DGs) ideal placement and sizing within the network, showing improvements in voltage profiles and decreased power losses. An outline of the efficiency benefits attained by the SHO algorithm is given in this section.

Table 8 Results Summary Using SHO Algorithm



```
Summary of Results Comparison:
                 Variable                     Before_DG     After_DG
    ____________________________________     __________    _________

    'Min Voltage (p.u)'                       '0.91309'     '0.9922'
    'Min Voltage at Bus Location'             '18'          '18'
    'Total Active Power Losses (kW)'          '202.6771'    '18.3194'
    'Total Active Power Losses (%)'           'NA'          '90.9613'
    'Total Reactive Power Losses (kVAR)'      '135.141'     '13.8962'
    'Total Reactive Power Losses (%)'         'NA'          '89.7173'
    'Power Factor'                            '0.8493'      '0.94739'

Additional Information related to DGs:
              Variable                                  Value
    ______________________________    _________________________________________

    'DG Type'                         '3'
    'No of DGs'                       '3'
    'Location of DGs (Bus Number)'    '30  12  24'
    'Sizes of DGs in kW'              '1033.1426      876.16707      756.45893'
    'Sizes of DGs in kVAR'            '840.551      675.122      963.7898'
    'MOI'                             '0.070631'
```

5.1.2 Backward Forward Sweep (BFS) Analysis of Network Using ABC Algorithm:

Below is the analysis of main parameters obtained using BFS method with ABC Algorithm:

5.1.2.1 Active Power Loss (APL) in term of DG placement:

Here is the graphical representation of Active Power Loss (APL) in fig 27 showing before and after placement of DGs optimally for Power factor improvement using BFS Method with ABC Algorithm.

5.1.2.2 Reactive Power Loss (RPL) in term of DG placement:

Here is the graphical representation of Reactive Power Loss (RPL) in fig 28 showing before and after placement of DGs optimally for Power factor improvement using BFS Method with ABC Algorithm.

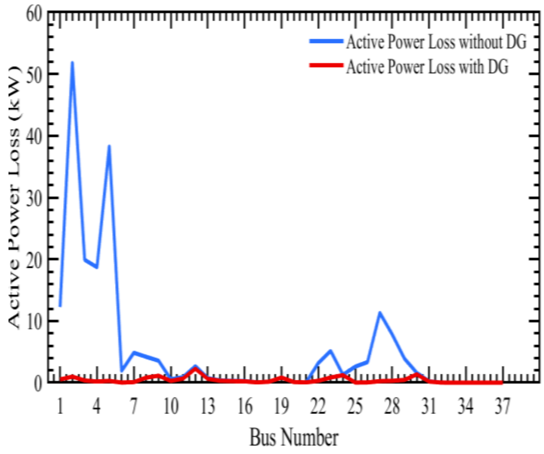


Figure 27 Active Power Loss (APL) in term of DG placement

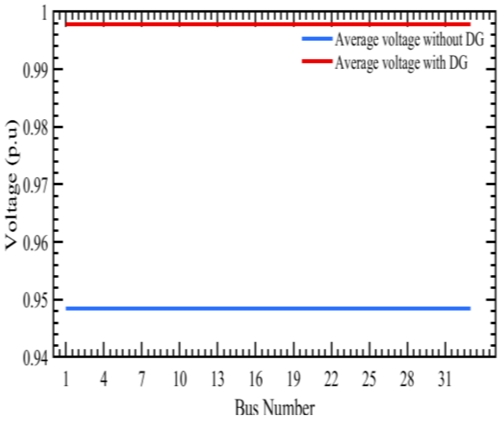


Figure 29 Average Voltage (Vavg)

showing before and after placement of DGs

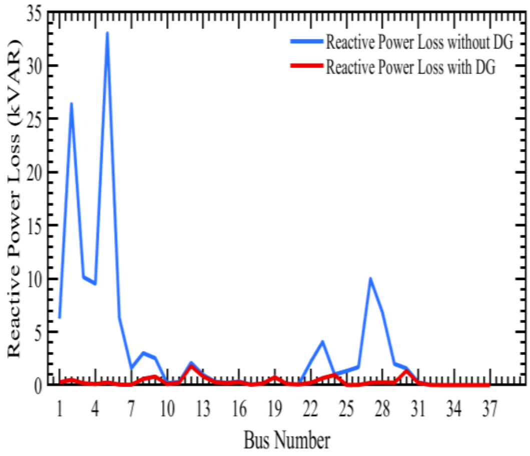


Figure 28 Reactive Power Loss (RPL) showing before and after placement of DGs

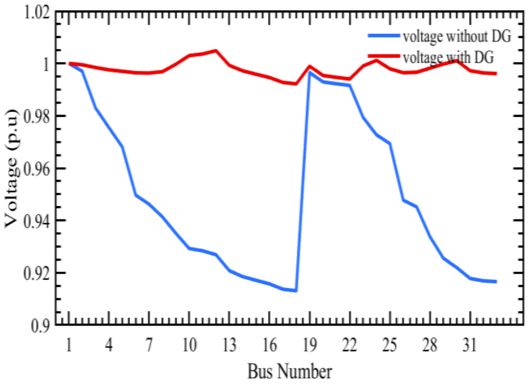


Figure 30 of Minimum Voltage (Vmin)

showing before and after placement of DGs

5.1.2.3 Average Voltage (Vavg) in term of DG placement:

Here is the graphical representation of Average Voltage (V_{avg}) in fig 28 showing before and after placement of DGs optimally for Power factor improvement using BFS Method with ABC Algorithm.

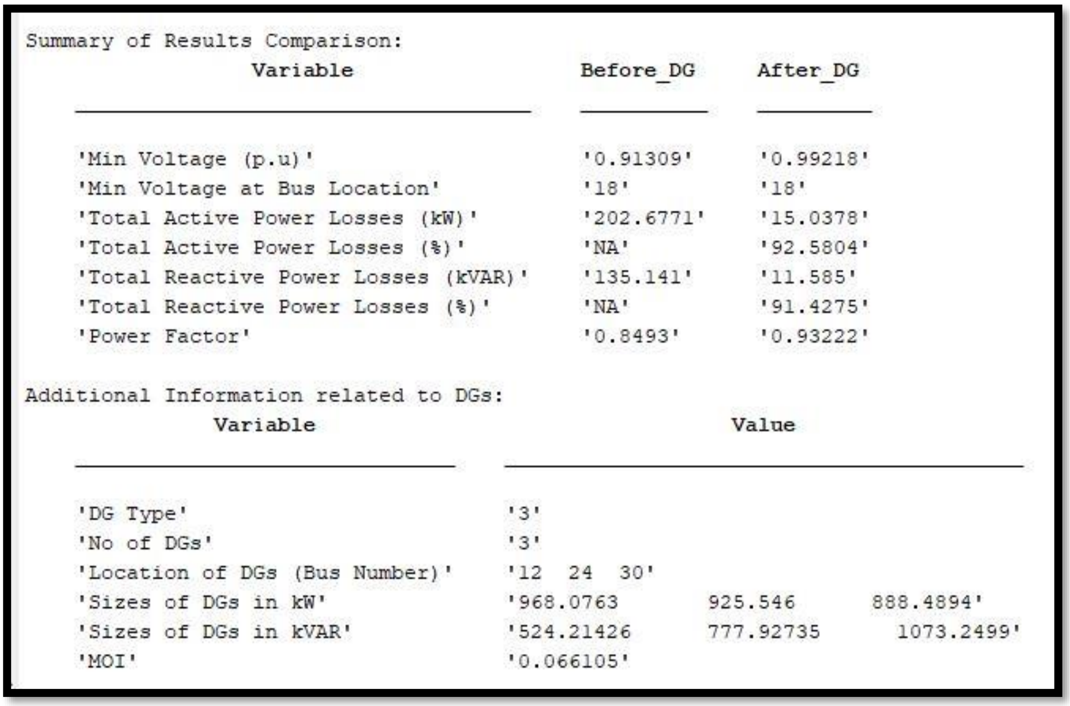
5.1.2.4 Minimum Voltage (Vmin) in term of DG placement:

Here is the graphical representation of Minimum Voltage (V_{min}) in fig 30 showing before and after placement of DGs optimally for Power factor improvement using BFS Method with ABC Algorithm.

5.1.2.5 Results Summary Using ABC Algorithm:

The impact of DG placement is shown in the results summary using the ABC algorithm, with a focus on how it affects voltage stability and power loss reduction. A quick comparison of the ABC algorithm's performance against alternative approaches is provided in this section.

Table 9 Results Summary Using ABC Algorithm



```
Summary of Results Comparison:
                 Variable                         Before_DG     After_DG

    ____________________________________         __________    _________

    'Min Voltage (p.u)'                          '0.91309'     '0.99218'
    'Min Voltage at Bus Location'                '18'          '18'
    'Total Active Power Losses (kW)'             '202.6771'    '15.0378'
    'Total Active Power Losses (%)'              'NA'          '92.5804'
    'Total Reactive Power Losses (kVAR)'         '135.141'     '11.585'
    'Total Reactive Power Losses (%)'            'NA'          '91.4275'
    'Power Factor'                               '0.8493'      '0.93222'

Additional Information related to DGs:
              Variable                                   Value

    ______________________________      __________________________________________

    'DG Type'                           '3'
    'No of DGs'                         '3'
    'Location of DGs (Bus Number)'      '12  24  30'
    'Sizes of DGs in kW'                '968.0763      925.546      888.4894'
    'Sizes of DGs in kVAR'              '524.21426     777.92735      1073.2499'
    'MOI'                               '0.066105'
```

5.1.3 Comparison of Convergence Curve between SHO and ABC Algorithm:

Here is the graphical representation of Convergence Curve showing comparison between SHO and ABC algorithm:

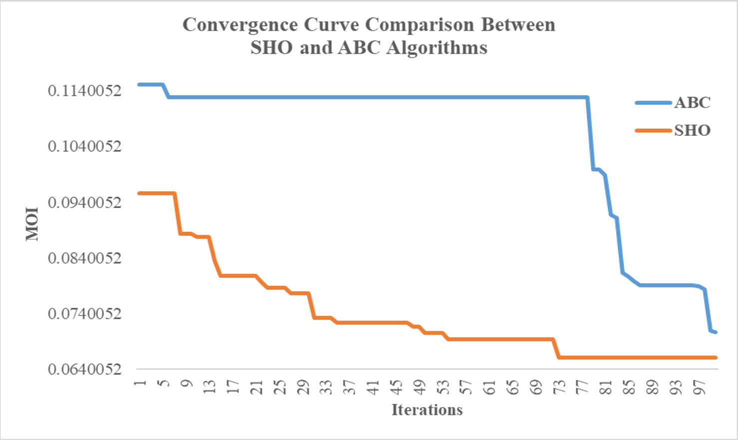


Figure 31 Comparison of Convergence Curve between SHO and ABC Algorithm

5.2 IEEE 69 Bus Network System:

The IEEE 69-bus system is a standard test case for distribution networks, featuring 69 buses and 68 branches with a total load of 3.8 MW and 2.69 MVAR. It’s commonly used to study power flow, voltage control, and the impact of distributed generation in real-world scenarios.

Here is the Torrit network single line diagram

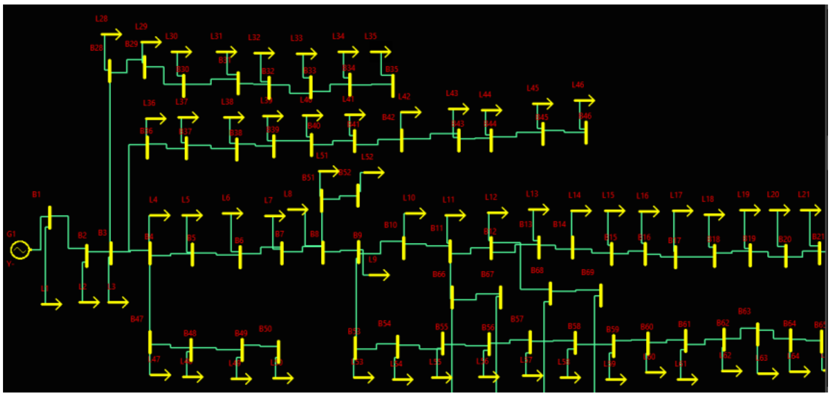


Figure 32 Torrit View of IEEE 69 bus network

5.2.1 Backward Forward Sweep (BFS) Analysis of Network Using SHO Algorithm:

Below is the analysis of main parameters obtained using BFS method with SHO Algorithm:

5.2.1.1 Active Power Loss (APL) in term of DG placement:

Here is the graphical representation of Active Power Loss (APL) in fig. 33 showing before and after placement of DGs optimally for Power factor improvement using BFS Method with SHO Algorithm

5.2.1.2 Reactive Power Loss (RPL) in term of DG placement:

Here is the graphical representation of Reactive Power Loss (RPL) in fig 34 showing before and after placement of DGs optimally for Power factor improvement using BFS Method with SHO Algorithm:

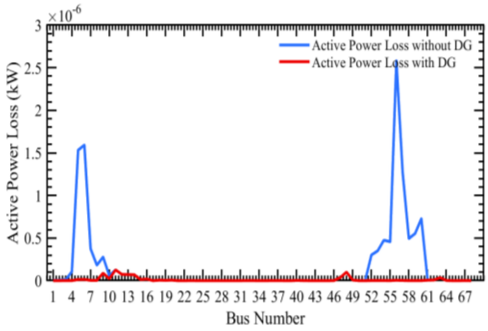


Figure 33 Active Power Loss (APL) showing before and after placement of DGs

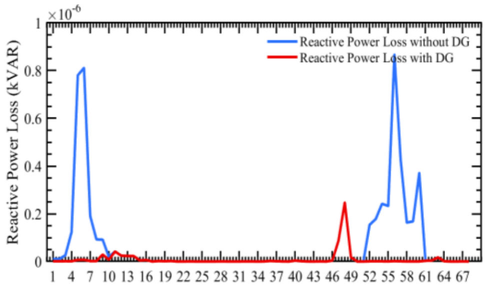


Figure 34 Reactive Power Loss (RPL) showing before and after placement of DGs

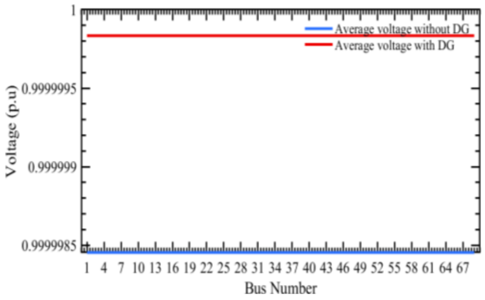


Figure 35 Average Voltage (Vavg) showing before and after placement of DGs

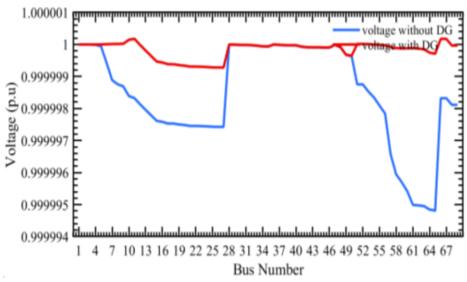


Figure 36 Minimum Voltage (Vmin) showing before and after placement of DG

5.2.1.3 Average Voltage (V_{avg}) in term of DG placement:

Here is the graphical representation of Average Voltage (V_{avg}) in fig 35 showing before and after placement of DGs optimally for Power factor improvement using BFS Method with SHO Algorithm.

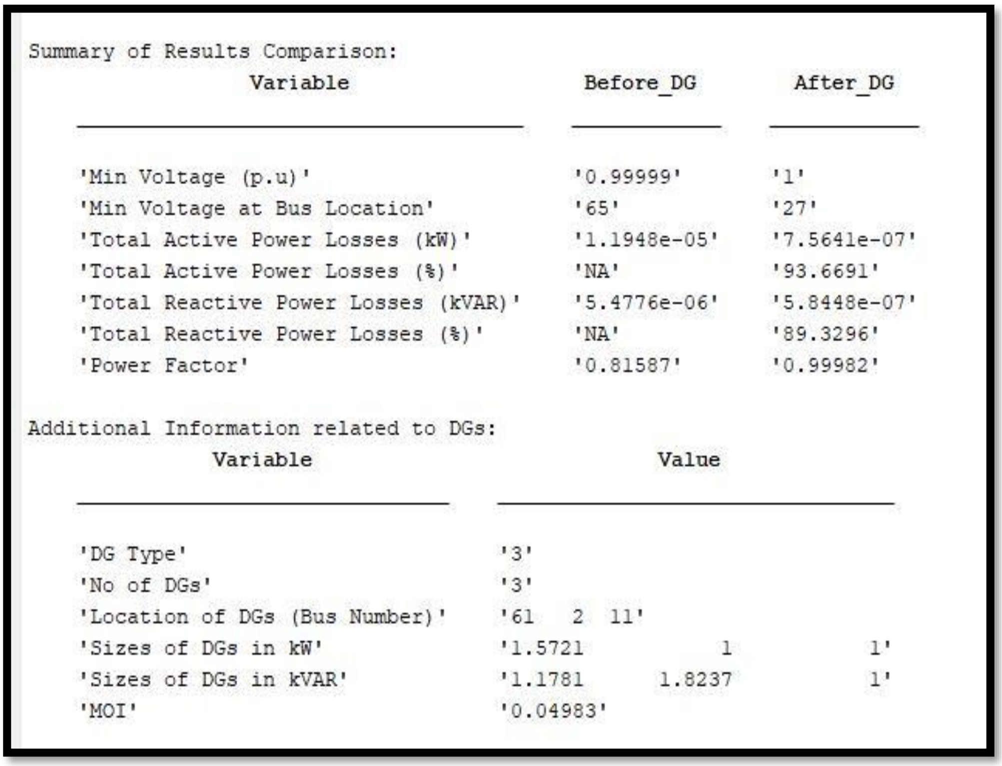
5.2.1.4 Minimum Voltage (V_{min}) in term of DG placement:

Here is the graphical representation of Minimum Voltage (V_{min}) in fig 36 showing before and after placement of DGs optimally for Power factor improvement using BFS Method with SHO Algorithm.

5.2.1.5 Results Summary Using SHO Algorithm:

An outline of the efficiency benefits attained by the SHO algorithm is given in this section.

Table 10 Results Summary Using SHO Algorithm



```
Summary of Results Comparison:
                Variable                        Before_DG        After_DG

    ____________________________________     ____________     ____________

    'Min Voltage (p.u)'                      '0.99999'        '1'
    'Min Voltage at Bus Location'            '65'             '27'
    'Total Active Power Losses (kW)'         '1.1948e-05'     '7.5641e-07'
    'Total Active Power Losses (%)'          'NA'             '93.6691'
    'Total Reactive Power Losses (kVAR)'     '5.4776e-06'     '5.8448e-07'
    'Total Reactive Power Losses (%)'        'NA'             '89.3296'
    'Power Factor'                           '0.81587'        '0.99982'

Additional Information related to DGs:
             Variable                            Value

    ______________________________    ________________________________

    'DG Type'                         '3'
    'No of DGs'                       '3'
    'Location of DGs (Bus Number)'    '61   2  11'
    'Sizes of DGs in kW'              '1.5721           1           1'
    'Sizes of DGs in kVAR'            '1.1781      1.8237           1'
    'MOI'                             '0.04983'
```

5.2.2 Backward Forward Sweep (BFS) Analysis of Network Using ABC Algorithm:

Below is the analysis of main parameters obtained using BFS method with ABC Algorithm:

5.2.2.1 Active Power Loss (APL) in term of DG placement:

Here is the graphical representation of Active Power Loss (APL) in fig. 37 showing before and after placement of DGs optimally for Power factor improvement using BFS Method with ABC Algorithm:

5.2.2.2 Reactive Power Loss (RPL) in term of DG placement:

Here is the graphical representation of Reactive Power Loss (RPL) in fig. 38 showing before and after placement of DGs optimally for Power factor improvement using BFS Method with ABC Algorithm.

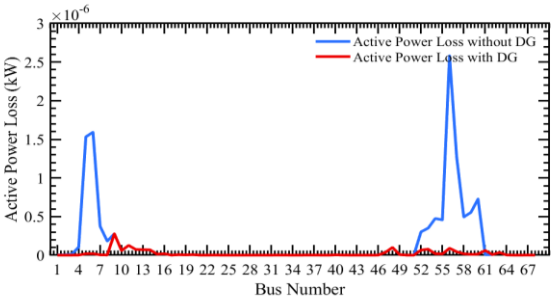


Figure 37 Active Power Loss (APL) showing before and after placement of DGs

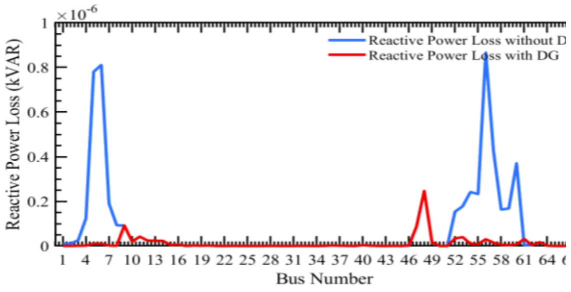


Figure 38 Reactive Power Loss (RPL) showing before and after placement of DGs

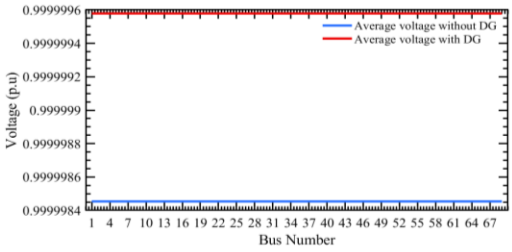


Figure 39 Average Voltage (Vavg) showing before and after placement of DGs

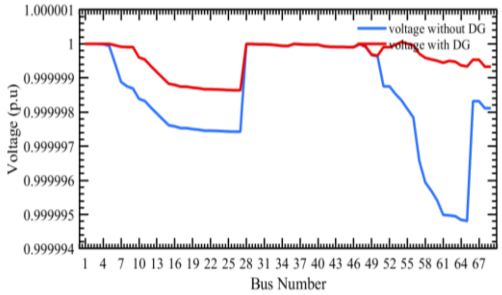


Figure 40 Minimum Voltage (Vmin) showing before and after placement of DGs

5.2.2.3 Minimum Voltage (Vmin) in term of DG placement:

Here is the graphical representation of Minimum Voltage (V_{min}) showing before and after placement of DGs optimally for Power factor improvement using BFS Method with ABC Algorithm.

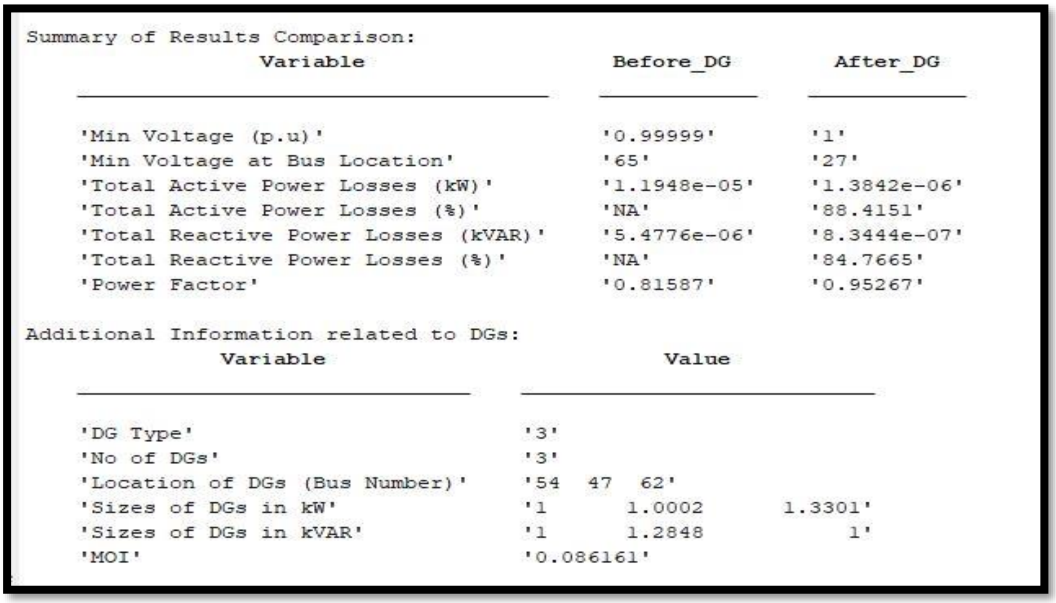
5.2.2.4 Average Voltage (V_{avg}) in term of DG placement:

Here is the graphical representation of Average Voltage (V_{avg}) in fig 39 showing before and after placement of DGs optimally for Power factor improvement using BFS Method with ABC Algorithm.

5.2.2.5 Results Summary Using ABC Algorithm:

The impact of DG placement is shown in the results summary using the ABC algorithm, with a focus on how it affects voltage stability and power loss reduction. A quick comparison of the ABC algorithm's performance against alternative approaches is provided in this section.

Table 11 Results Summary Using ABC Algorithm



```
Summary of Results Comparison:
                 Variable                           Before_DG        After_DG
    ____________________________________         ____________     ____________

    'Min Voltage (p.u)'                          '0.99999'        '1'
    'Min Voltage at Bus Location'                '65'             '27'
    'Total Active Power Losses (kW)'             '1.1948e-05'     '1.3842e-06'
    'Total Active Power Losses (%)'              'NA'             '88.4151'
    'Total Reactive Power Losses (kVAR)'         '5.4776e-06'     '8.3444e-07'
    'Total Reactive Power Losses (%)'            'NA'             '84.7665'
    'Power Factor'                               '0.81587'        '0.95267'

Additional Information related to DGs:
              Variable                             Value
    ______________________________    ___________________________

    'DG Type'                         '3'
    'No of DGs'                       '3'
    'Location of DGs (Bus Number)'    '54   47   62'
    'Sizes of DGs in kW'              '1      1.0002      1.3301'
    'Sizes of DGs in kVAR'            '1      1.2848           1'
    'MOI'                             '0.086161'
```

5.2.3 Comparison of Convergence Curve between SHO and ABC Algorithm:

Here is the graphical representation of Convergence Curve showing comparison between SHO and ABC algorithm:

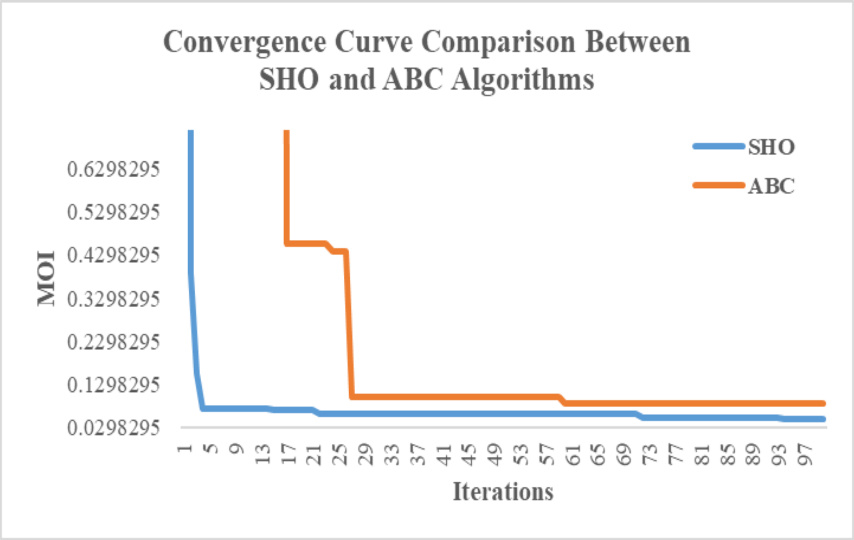


Figure 41 Comparison of Convergence Curve between SHO and ABC Algorithm

5.3 IESCO 15 Bus Network System:

The network in Figure 50 depicts the Torrit visualization of IESCO regional distributive network, comprising 15 buses and 14 branches. The total active and reactive load demand of this network is 1334.4 kW and 1439.5 kVAR respectively.

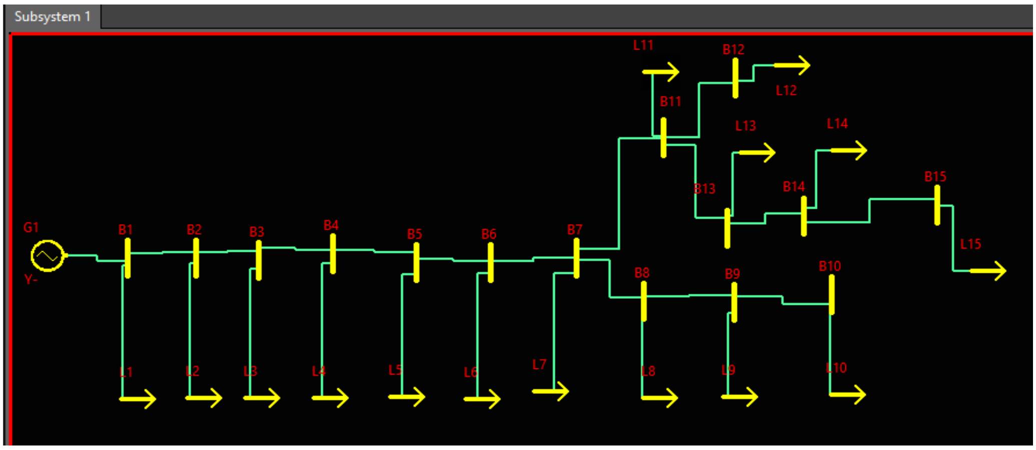


Figure 42 Torrit view of IESCO 15 Bus Network System

5.3.1 Backward Forward Sweep (BFS) Analysis of Network Using SHO Algorithm:

Below is the analysis of main parameters obtained using BFS method with SHO Algorithm:

5.3.1.1 Active Power Loss (APL) in term of DG placement:

Here is the graphical representation of Active Power Loss (APL) in fig 43showing before and after placement of DGs optimally for Power factor improvement using BFS Method with SHO Algorithm.

5.3.1.2 Reactive Power Loss (RPL) in term of DG placement:

Here is the graphical representation of Reactive Power Loss (RPL) in fig 44 showing before and after placement of DGs optimally for Power factor improvement using BFS Method with SHO Algorithm:

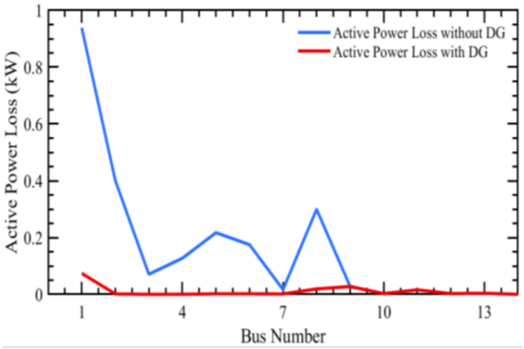


Figure 43 Active Power Loss (APL) showing before and after placement of DGs

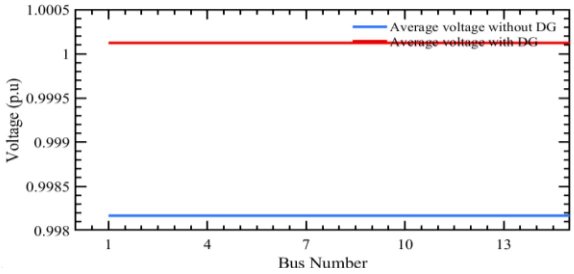


Figure 45 Average Voltage (Vavg) showing before and after placement of DGs

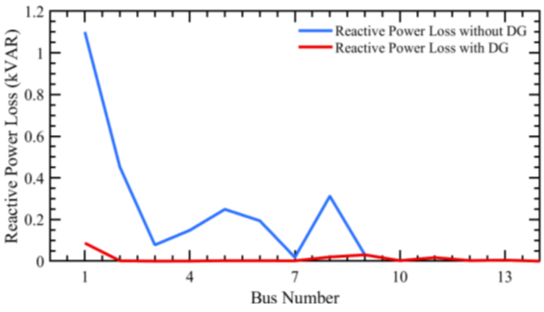


Figure 44 Reactive Power Loss (RPL) showing before and after placement of DGs

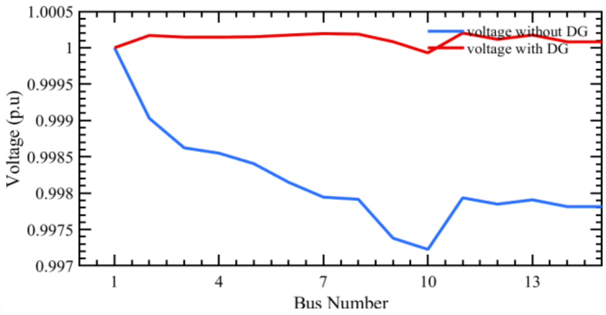


Figure 46 Minimum Voltage (Vmin) showing before and after placement of DG

5.3.1.3 Average Voltage (V_{avg}) in term of DG placement:

Here is the graphical representation of Average Voltage (V_{avg}) in fig 45 showing before and after placement of DGs optimally for Power factor improvement using BFS Method with SHO Algorithm.:

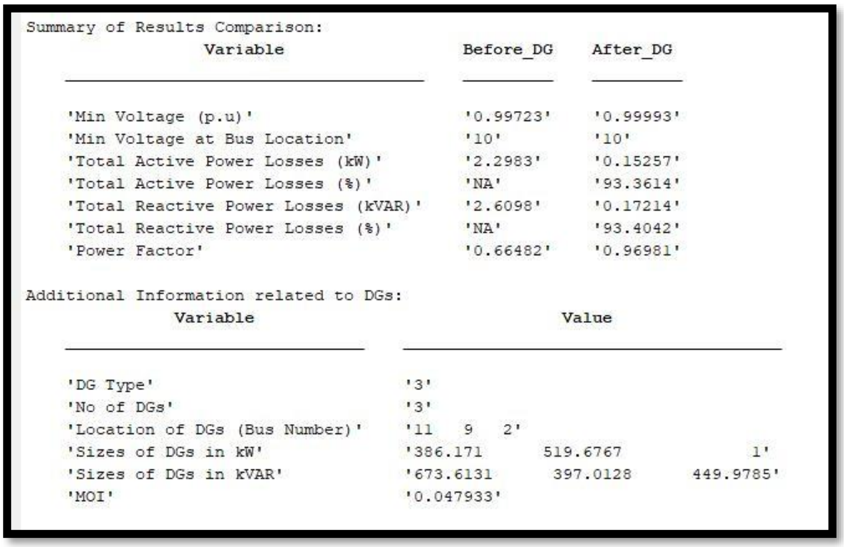
5.3.1.4 Minimum Voltage (V_{min}) in term of DG placement:

Here is the graphical representation of Minimum Voltage (V_{min}) in fig 46 showing before and after placement of DGs optimally for Power factor improvement using BFS Method with SHO Algorithm.

5.3.1.5 Results Summary Using SHO Algorithm:

The SHO algorithm's results summary emphasizes the Distributed Generators' (DGs) ideal placement and sizing within the network, showing improvements in voltage profiles and decreased power losses. An outline of the efficiency benefits attained by the SHO algorithm is given in this section.

Table 12 Results Summary Using SHO Algorithm



```
Summary of Results Comparison:
                 Variable                     Before_DG    After_DG
     ____________________________________    _________    _________

     'Min Voltage (p.u)'                     '0.99723'    '0.99993'
     'Min Voltage at Bus Location'           '10'         '10'
     'Total Active Power Losses (kW)'        '2.2983'     '0.15257'
     'Total Active Power Losses (%)'         'NA'         '93.3614'
     'Total Reactive Power Losses (kVAR)'    '2.6098'     '0.17214'
     'Total Reactive Power Losses (%)'       'NA'         '93.4042'
     'Power Factor'                          '0.66482'    '0.96981'

Additional Information related to DGs:
              Variable                                Value
     ______________________________    ______________________________________

     'DG Type'                         '3'
     'No of DGs'                       '3'
     'Location of DGs (Bus Number)'    '11    9    2'
     'Sizes of DGs in kW'              '386.171      519.6767            1'
     'Sizes of DGs in kVAR'            '673.6131      397.0128      449.9785'
     'MOI'                             '0.047933'
```

5.3.2 Backward Forward Sweep (BFS) Analysis of Network Using ABC Algorithm:

Below is the analysis of main parameters obtained using BFS method with ABC Algorithm:

5.3.2.1 Active Power Loss (APL) in term of DG placement:

Here is the graphical representation of Active Power Loss (APL) in fig.47 showing before and after placement of DGs optimally for Power factor improvement using BFS Method with ABC Algorithm.

5.3.2.2 Reactive Power Loss (RPL) in term of DG placement:

Here is the graphical representation of Reactive Power Loss (RPL) in fig.48 showing before and after placement of DGs optimally for Power factor improvement using BFS Method with ABC Algorithm.

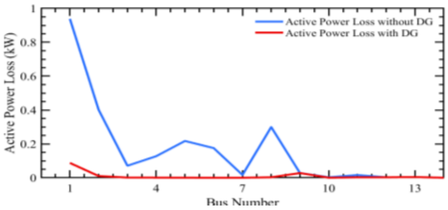


Figure 47 Active Power Loss (APL) showing before and after placement of DGs

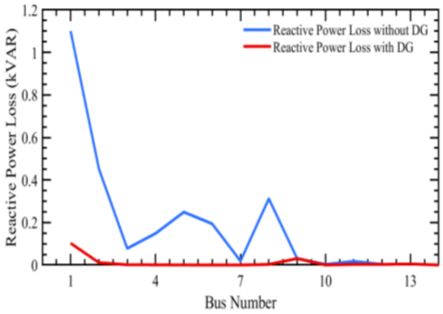


Figure 48 Reactive Power Loss (RPL) showing before and after placement of DGs

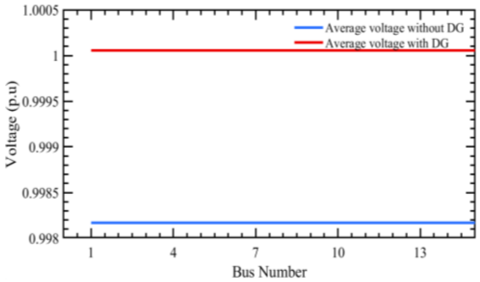


Figure 49 Average Voltage (Vavg) showing before and after placement of DGs

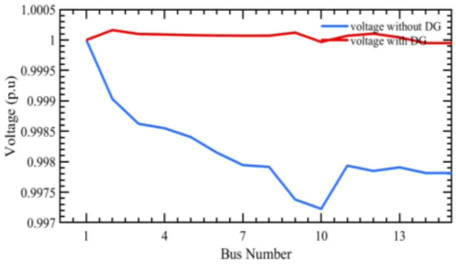


Figure 50 Minimum Voltage (Vmin) showing before and after placement of DGs

5.3.2.3 Average Voltage (Vavg) in term of DG placement:

Here is the graphical representation of Average Voltage (V_{avg}) in fig.49 showing before and after placement of DGs optimally for Power factor improvement using BFS Method with ABC Algorithm.

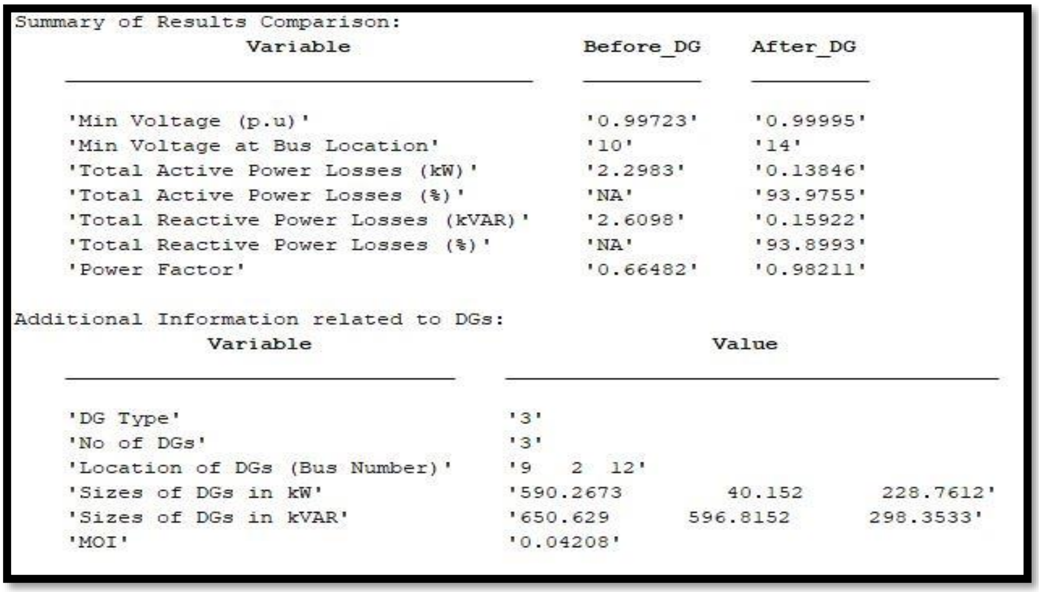
5.3.2.4 Minimum Voltage (Vmin) in term of DG placement:

Here is the graphical representation of Minimum Voltage (V_{min}) in fig.50 showing before and after placement of DGs optimally for Power factor improvement using BFS Method with ABC Algorithm.

5.3.2.5 Results Summary Using ABC Algorithm:

The impact of DG placement is shown in the results summary using the ABC algorithm, with a focus on how it affects voltage stability and power loss reduction. A quick comparison of the ABC algorithm's performance against alternative approaches is provided in this section.

Table 13 Results Summary Using ABC Algorithm



```
Summary of Results Comparison:
                  Variable                       Before_DG     After_DG
    ____________________________________        _________     _________

    'Min Voltage (p.u)'                         '0.99723'     '0.99995'
    'Min Voltage at Bus Location'               '10'          '14'
    'Total Active Power Losses (kW)'            '2.2983'      '0.13846'
    'Total Active Power Losses (%)'             'NA'          '93.9755'
    'Total Reactive Power Losses (kVAR)'        '2.6098'      '0.15922'
    'Total Reactive Power Losses (%)'           'NA'          '93.8993'
    'Power Factor'                              '0.66482'     '0.98211'

Additional Information related to DGs:
               Variable                                   Value
    ______________________________      _______________________________________

    'DG Type'                           '3'
    'No of DGs'                         '3'
    'Location of DGs (Bus Number)'      '9   2  12'
    'Sizes of DGs in kW'                '590.2673         40.152        228.7612'
    'Sizes of DGs in kVAR'              '650.629       596.8152       298.3533'
    'MOI'                               '0.04208'
```

5.3.3 Comparison of Convergence Curve between SHO and ABC Algorithm:

Here is the graphical representation of Convergence Curve showing comparison between SHO and ABC algorithm:

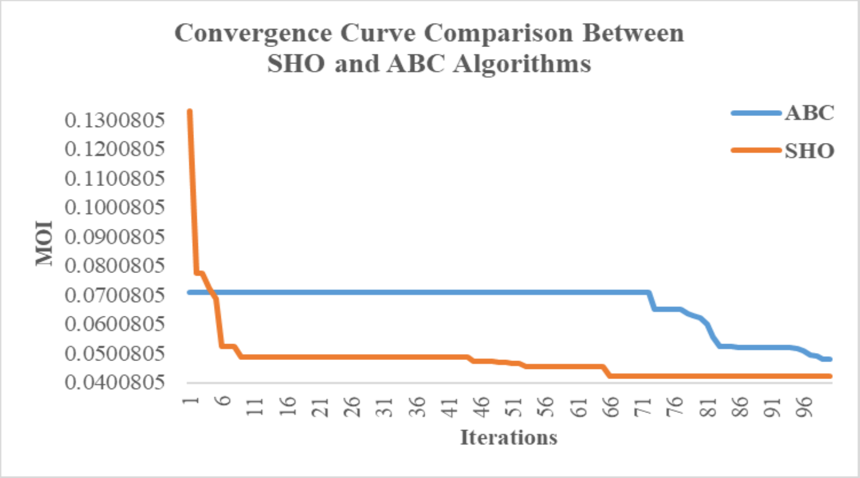


Figure 51 Comparison of Convergence Curve between SHO and ABC Algorithm

5.4 IESCO 18 Bus Network System:

The network in Figure 61 depicts the Torrit visualization of the IESCO regional distributive network, comprising 18 buses and 17 branches. The total active and reactive load demand of this network is 1390 kW and 1412 kVAR respectively.

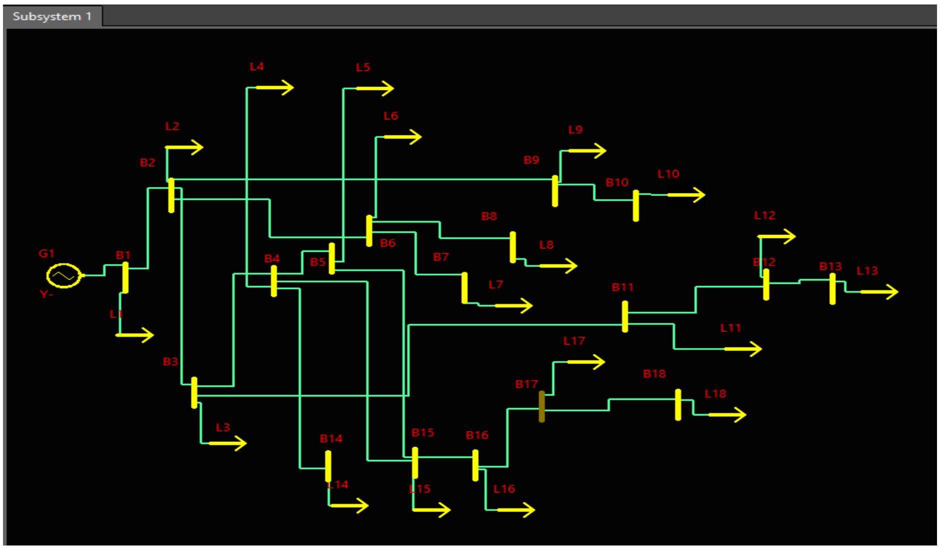


Figure 52 Torrit view of IESCO 18 Bus Network System

5.4.1 Backward Forward Sweep (BFS) Analysis of Network Using SHO Algorithm:

Below is the analysis of main parameters obtained using BFS method with SHO Algorithm:

5.4.1.1 Active Power Loss (APL) in term of DG placement:

Here is the graphical representation of Active Power Loss (APL) showing before and after placement of DGs optimally for Power factor improvement using BFS Method with SHO Algorithm:

5.4.1.2 Reactive Power Loss (RPL) in term of DG placement:

Here is the graphical representation of Reactive Power Loss (RPL) showing before and after placement of DGs optimally for Power factor improvement using BFS Method with SHO Algorithm:

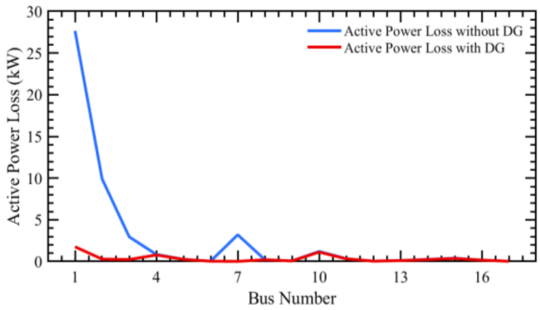


Figure 53 Active Power Loss (APL) showing before and after placement of DGs

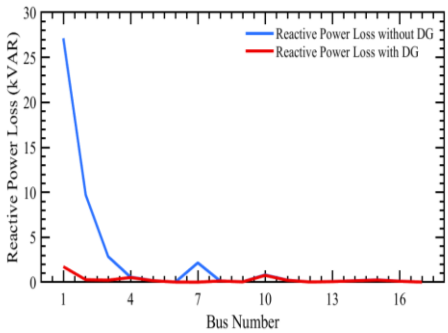


Figure 54 Reactive Power Loss (RPL) showing before and after placement of DGs

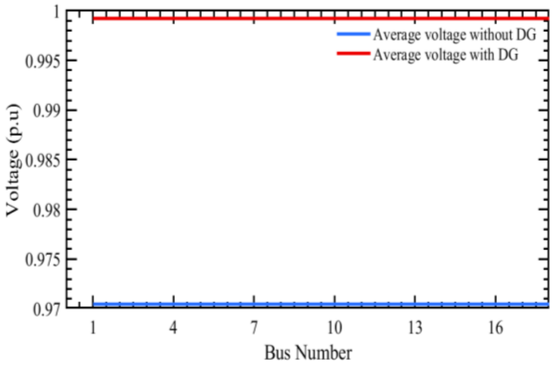


Figure 55 Average Voltage (Vavg) showing before and after placement of DGs

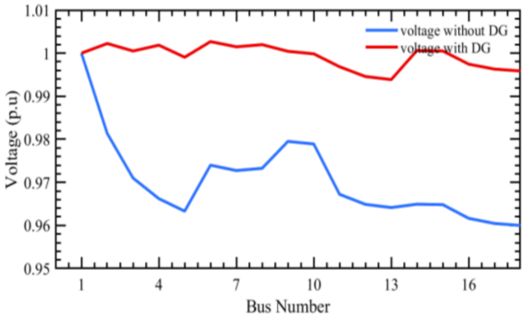


Figure 56 Minimum Voltage (Vmin) showing before and after placement of DGs

5.4.1.3 Average Voltage (V_{avg}) in term of DG placement:

Here is the graphical representation of Average Voltage (V_{avg}) showing before and after placement of DGs optimally for Power factor improvement using BFS Method with SHO Algorithm.

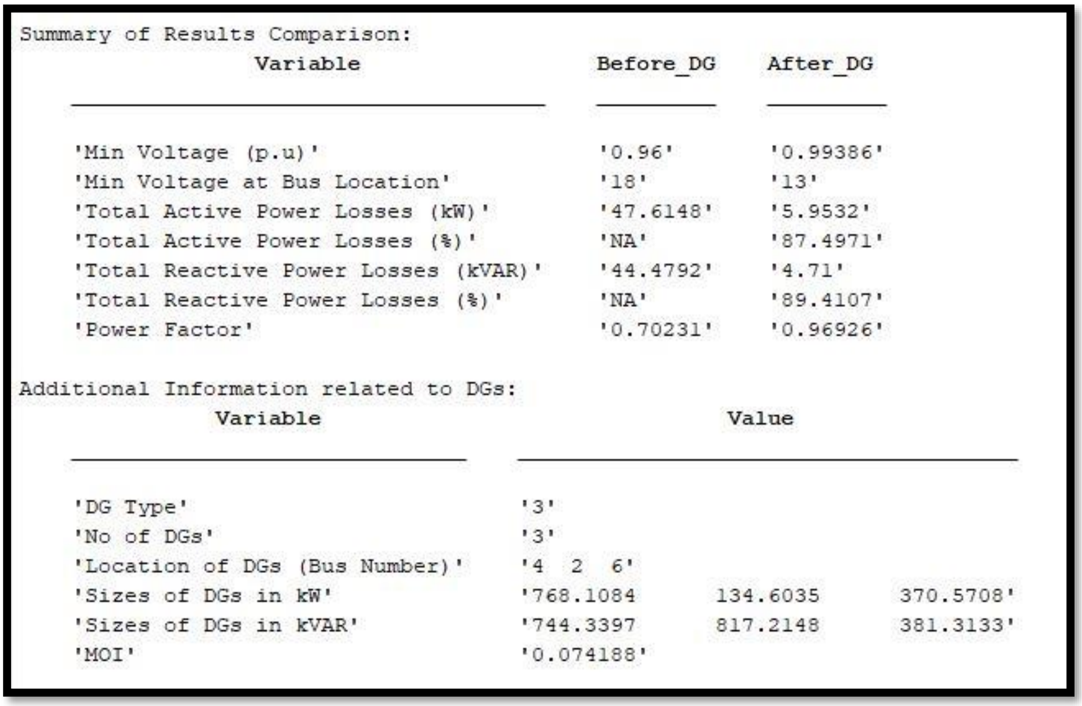
5.4.1.4 Minimum Voltage (V_{min}) in term of DG placement:

Here is the graphical representation of Minimum Voltage (V_{min}) showing before and after placement of DGs optimally for Power factor improvement using BFS Method with SHO Algorithm.

5.4.1.5 Results Summary Using SHO Algorithm:

An outline of the efficiency benefits attained by the SHO algorithm is given in this section.

Table 14 Results Summary Using SHO Algorithm



```
Summary of Results Comparison:
                 Variable                        Before_DG     After_DG
    ____________________________________        _________     _________

    'Min Voltage (p.u)'                         '0.96'        '0.99386'
    'Min Voltage at Bus Location'               '18'          '13'
    'Total Active Power Losses (kW)'            '47.6148'     '5.9532'
    'Total Active Power Losses (%)'             'NA'          '87.4971'
    'Total Reactive Power Losses (kVAR)'        '44.4792'     '4.71'
    'Total Reactive Power Losses (%)'           'NA'          '89.4107'
    'Power Factor'                              '0.70231'     '0.96926'

Additional Information related to DGs:
              Variable                                Value
    ______________________________    ______________________________________

    'DG Type'                         '3'
    'No of DGs'                       '3'
    'Location of DGs (Bus Number)'    '4   2   6'
    'Sizes of DGs in kW'              '768.1084      134.6035      370.5708'
    'Sizes of DGs in kVAR'            '744.3397      817.2148      381.3133'
    'MOI'                             '0.074188'
```

5.4.2 Backward Forward Sweep (BFS) Analysis of Network Using ABC Algorithm:

Below is the analysis of main parameters obtained using BFS method with ABC Algorithm:

5.4.2.1 Active Power Loss (APL) in term of DG placement:

Here is the graphical representation of Active Power Loss (APL) showing before and after placement of DGs optimally for Power factor improvement using BFS Method with ABC Algorithm.

5.4.2.2 Reactive Power Loss (RPL) in term of DG placement:

Here is the graphical representation of Reactive Power Loss (RPL) showing before and after placement of DGs optimally for Power factor improvement using BFS Method with ABC Algorithm.

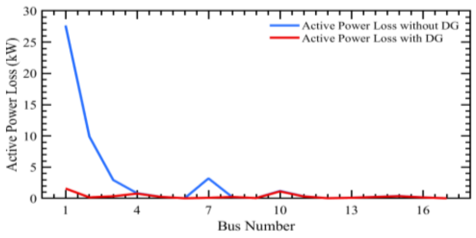


Figure 57 Active Power Loss (APL) showing before and after placement of DGs

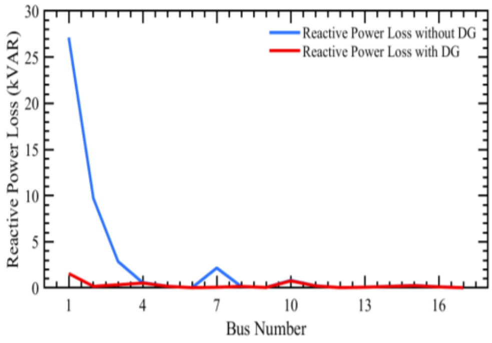


Figure 58 Reactive Power Loss (RPL) showing before and after placement of DGs

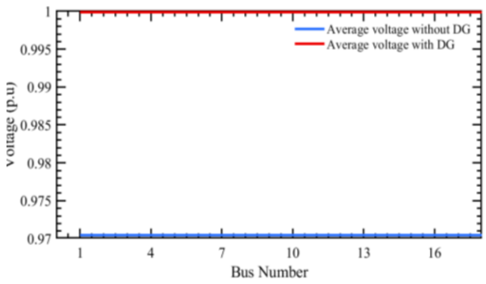


Figure 59 Average Voltage (Vavg) showing before and after placement of DGs

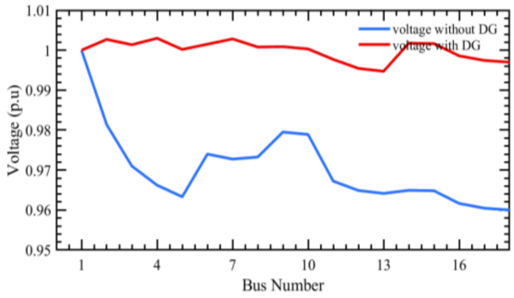


Figure 60 Minimum Voltage (Vmin) showing before and after placement of DG

5.4.2.3 Average Voltage (Vavg) in term of DG placement:

Here is the graphical representation of Average Voltage (V_{avg}) showing before and after placement of DGs optimally for Power factor improvement using BFS Method with ABC Algorithm.:

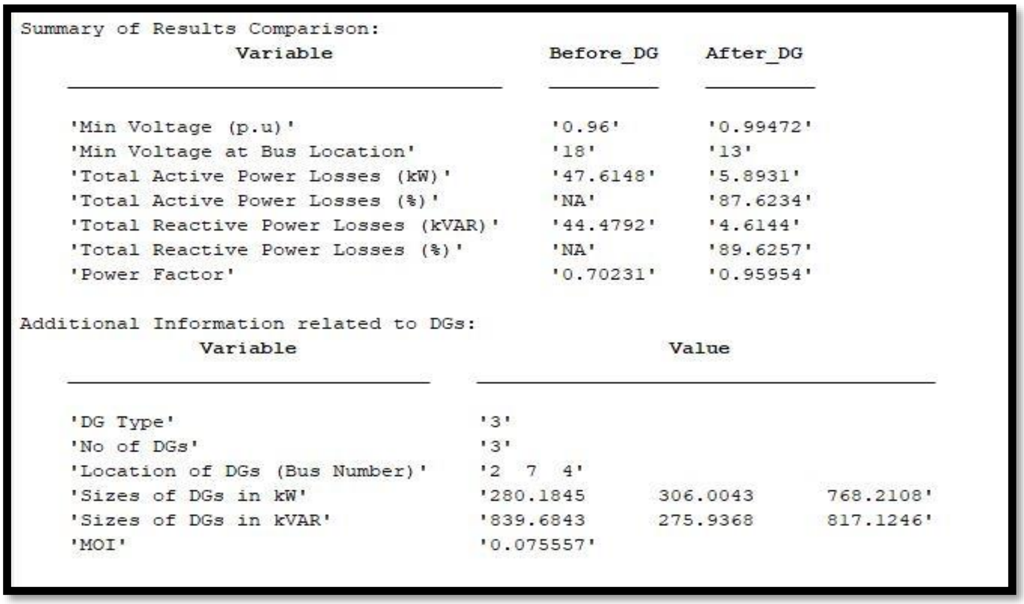
5.4.2.4 Minimum Voltage (Vmin) in term of DG placement:

Here is the graphical representation of Minimum Voltage (V_{min}) showing before and after placement of DGs optimally for Power factor improvement using BFS Method with ABC Algorithm.

5.4.2.5 Results Summary Using ABC Algorithm:

The impact of DG placement are shown in the results summary using the ABC algorithm, with a focus on how it affects voltage stability and power loss reduction. A quick comparison of the ABC algorithm's performance against alternative approaches is provided in this section.

Table 15 Results Summary Using ABC Algorithm



```
Summary of Results Comparison:
                 Variable                     Before_DG    After_DG
    ____________________________________     _________    _________

    'Min Voltage (p.u)'                       '0.96'       '0.99472'
    'Min Voltage at Bus Location'             '18'         '13'
    'Total Active Power Losses (kW)'          '47.6148'    '5.8931'
    'Total Active Power Losses (%)'           'NA'         '87.6234'
    'Total Reactive Power Losses (kVAR)'      '44.4792'    '4.6144'
    'Total Reactive Power Losses (%)'         'NA'         '89.6257'
    'Power Factor'                            '0.70231'    '0.95954'

Additional Information related to DGs:
              Variable                               Value
    ______________________________    ______________________________________

    'DG Type'                         '3'
    'No of DGs'                       '3'
    'Location of DGs (Bus Number)'    '2   7   4'
    'Sizes of DGs in kW'              '280.1845      306.0043      768.2108'
    'Sizes of DGs in kVAR'            '839.6843      275.9368      817.1246'
    'MOI'                             '0.075557'
```

5.4.3 Comparison of Convergence Curve between SHO and ABC Algorithm:

Here is the graphical representation of Convergence Curve showing comparison between SHO and ABC algorithm:

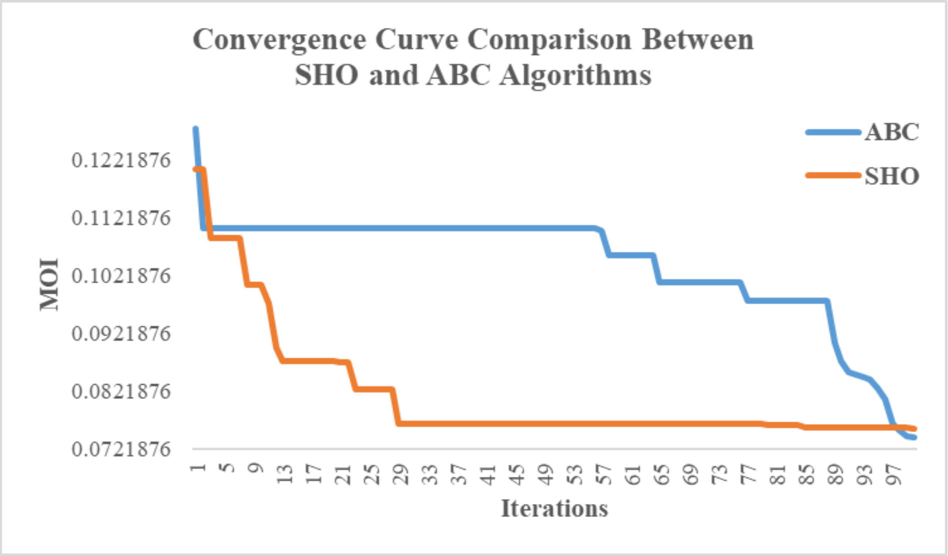


Figure 61 Comparison of Convergence Curve between SHO and ABC Algorithm

5.5 IESCO 20 Bus Network System:

The network in Figure 72 depicts the Torrit visualization of the IESCO regional distributive network, comprising 20 buses and 18 branches. The total active and reactive load demand of this network is 2234 kW and 2485 kVAR respectively.

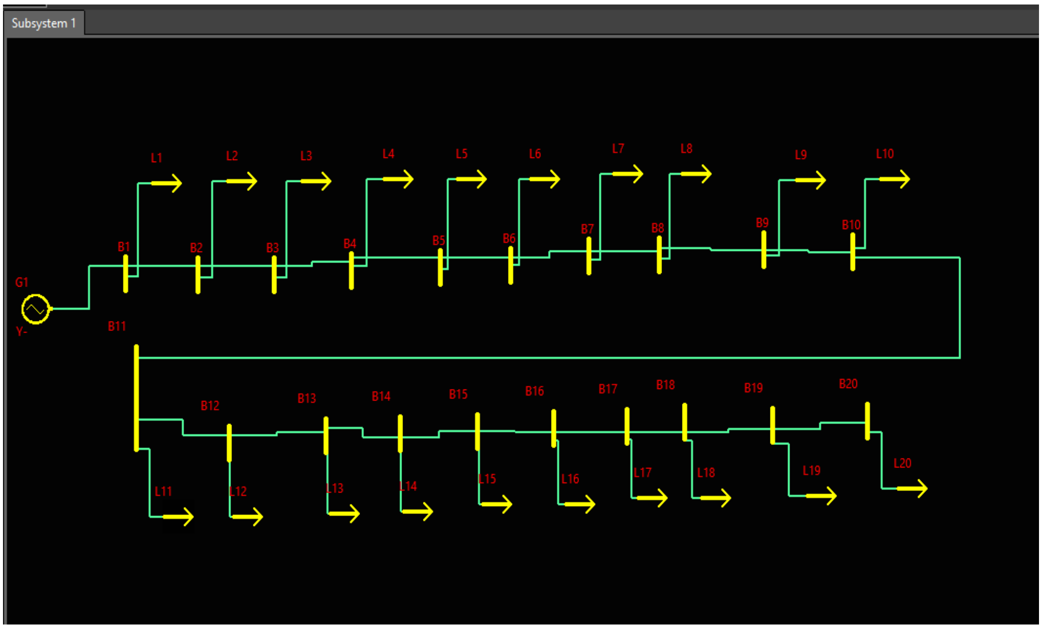


Figure 62 Torrit view of IESCO 20 Bus Network System

5.5.1 Backward Forward Sweep (BFS) Analysis of Network Using SHO Algorithm:

Below is the analysis of main parameters obtained using BFS method with SHO Algorithm:

5.5.1.1 Active Power Loss (APL) in term of DG placement:

Here is the graphical representation of Active Power Loss (APL) in fig.63 showing before and after placement of DGs optimally for Power factor improvement using BFS Method with SHO Algorithm

5.5.1.2 Reactive Power Loss (RPL) in term of DG placement:

Here is the graphical representation of Reactive Power Loss (RPL) in fig.64 showing before and after placement of DGs optimally for Power factor improvement using BFS Method with SHO Algorithm:

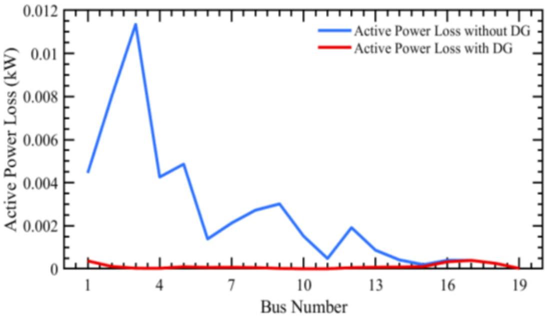


Figure 63 Active Power Loss (APL) showing before and after placement of DGs

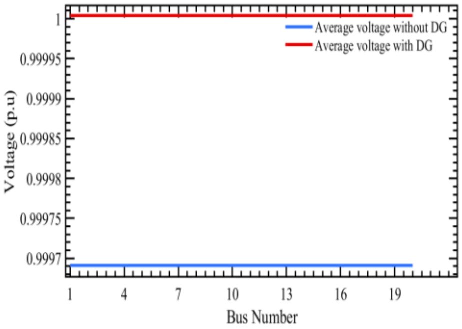


Figure 65 of Average Voltage (Vavg) showing before and after placement of DGs

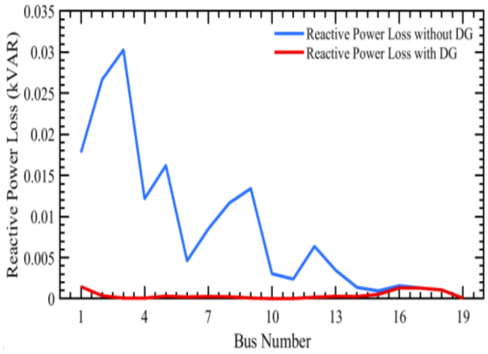


Figure 64 Reactive Power Loss (RPL) showing before and after placement of DG

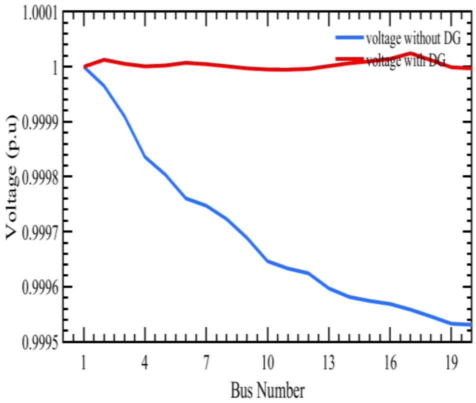


Figure 66 Minimum Voltage (Vmin) showing before and after placement of DGs

5.5.1.3 Average Voltage (V_{avg}) in term of DG placement:

Here is the graphical representation of Average Voltage (V_{avg}) in fig.65 showing before and after placement of DGs optimally for Power factor improvement using BFS Method with SHO Algorithm.

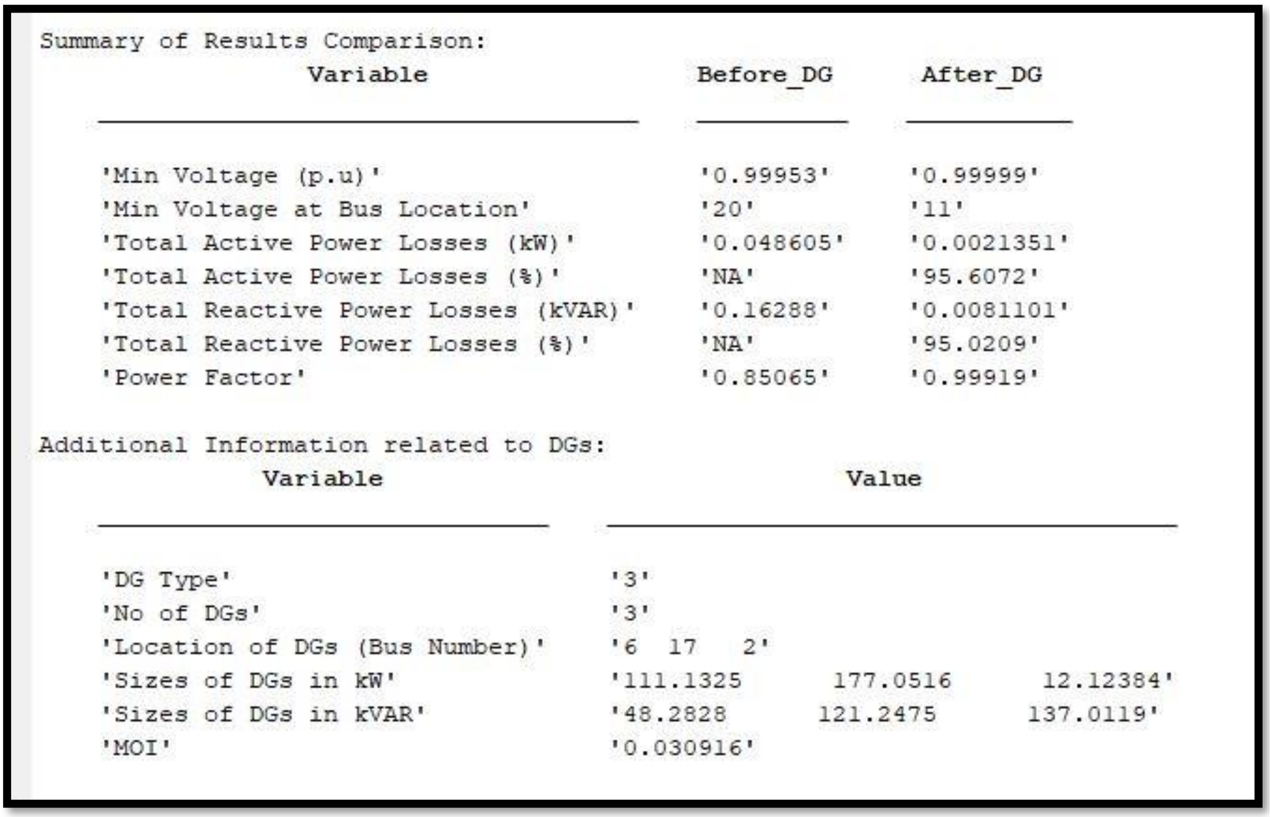
5.5.1.4 Minimum Voltage (V_{min}) in term of DG placement:

Here is the graphical representation of Minimum Voltage (V_{min}) in fig.66 showing before and after placement of DGs optimally for Power factor improvement using BFS Method with SHO Algorithm.

5.5.1.5 Results Summary Using SHO Algorithm:

An outline of the efficiency benefits attained by the SHO algorithm is given in this section.

Table 16 Results Summary Using SHO Algorithm



```
Summary of Results Comparison:
               Variable                          Before_DG      After_DG
   ____________________________________        __________     ___________

   'Min Voltage (p.u)'                          '0.99953'      '0.99999'
   'Min Voltage at Bus Location'                '20'           '11'
   'Total Active Power Losses (kW)'             '0.048605'     '0.0021351'
   'Total Active Power Losses (%)'              'NA'           '95.6072'
   'Total Reactive Power Losses (kVAR)'         '0.16288'      '0.0081101'
   'Total Reactive Power Losses (%)'            'NA'           '95.0209'
   'Power Factor'                               '0.85065'      '0.99919'

Additional Information related to DGs:
            Variable                                Value
   ______________________________    ______________________________________

   'DG Type'                         '3'
   'No of DGs'                       '3'
   'Location of DGs (Bus Number)'    '6  17   2'
   'Sizes of DGs in kW'              '111.1325      177.0516      12.12384'
   'Sizes of DGs in kVAR'            '48.2828     121.2475      137.0119'
   'MOI'                             '0.030916'
```

5.5.2 Backward Forward Sweep (BFS) Analysis of Network Using ABC Algorithm:

Below is the analysis of main parameters obtained using BFS method with ABC Algorithm:

5.5.2.1 Active Power Loss (APL) in term of DG placement:

Here is the graphical representation of Active Power Loss (APL) showing before and after placement of DGs optimally for Power factor improvement using BFS Method with ABC Algorithm.

5.5.2.2 Reactive Power Loss (RPL) in term of DG placement:

Here is the graphical representation of Reactive Power Loss (RPL) showing before and after placement of DGs optimally for Power factor improvement using BFS Method with ABC Algorithm.

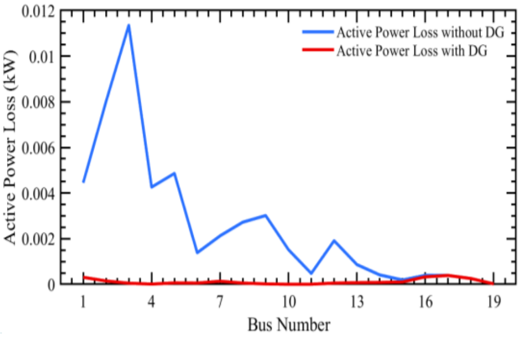


Figure 67 Active Power Loss (APL) showing before and after placement of DGs

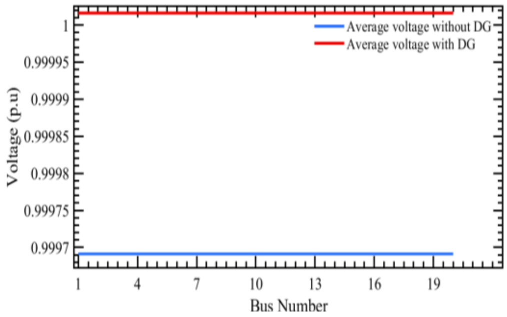


Figure 69 of Average Voltage (Vavg) showing before and after placement of DGs

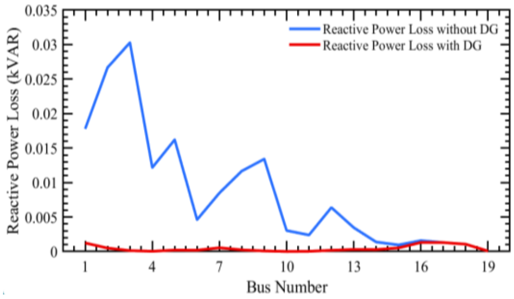


Figure 68 Reactive Power Loss (RPL) showing before and after placement of DG

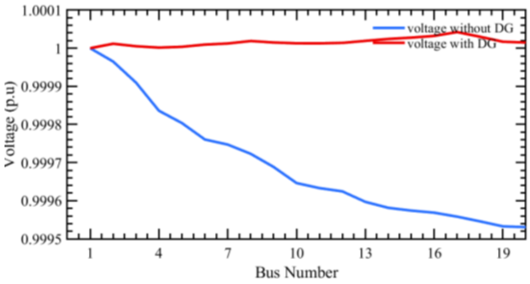


Figure 70 Minimum Voltage (Vmin) showing before and after placement of DGs

5.5.2.3 Average Voltage (Vavg) in term of DG placement:

Here is the graphical representation of Average Voltage (V_{avg}) showing before and after placement of DGs optimally for Power factor improvement using BFS Method with ABC Algorithm.

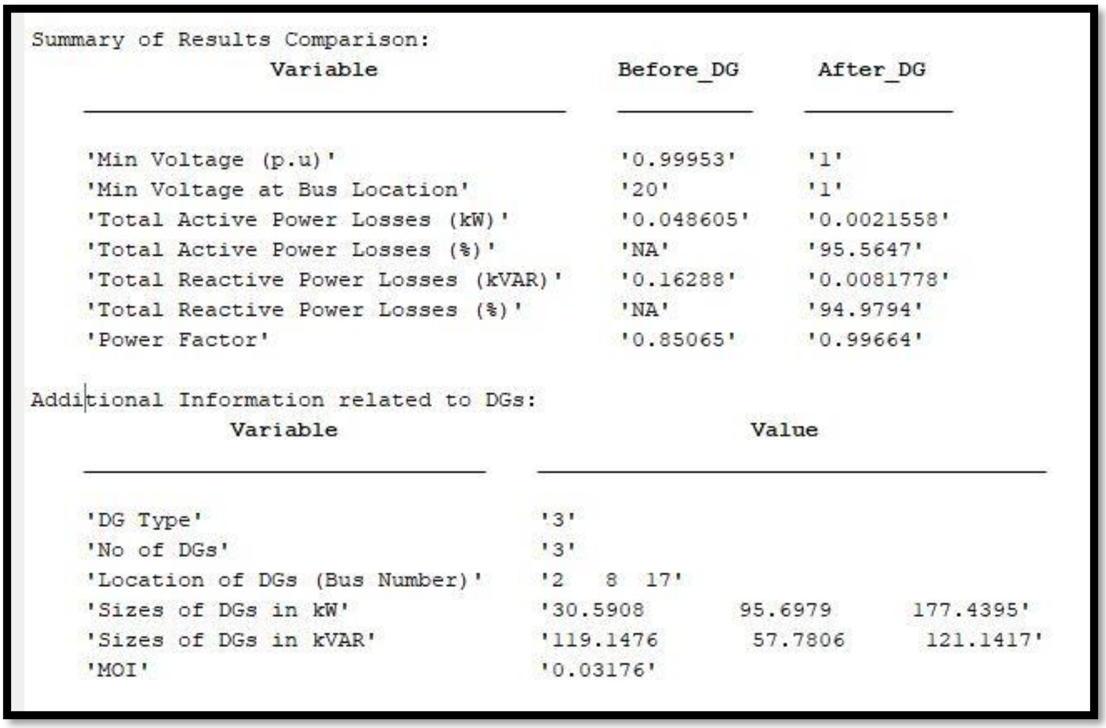
5.5.2.4 Minimum Voltage (Vmin) in term of DG placement:

Here is the graphical representation of Minimum Voltage (V_{min}) showing before and after placement of DGs optimally for Power factor improvement using BFS Method with ABC Algorithm.

5.5.2.5 Results Summary Using ABC Algorithm:

The impact of DG placement are shown in the results summary using the ABC algorithm, with a focus on how it affects voltage stability and power loss reduction. A quick comparison of the ABC algorithm's performance against alternative approaches is provided in this section.

Table 17 Results Summary Using ABC Algorithm



```
Summary of Results Comparison:
                 Variable                     Before_DG      After_DG
    ____________________________________     __________    ___________

    'Min Voltage (p.u)'                       '0.99953'     '1'
    'Min Voltage at Bus Location'             '20'          '1'
    'Total Active Power Losses (kW)'          '0.048605'    '0.0021558'
    'Total Active Power Losses (%)'           'NA'          '95.5647'
    'Total Reactive Power Losses (kVAR)'      '0.16288'     '0.0081778'
    'Total Reactive Power Losses (%)'         'NA'          '94.9794'
    'Power Factor'                            '0.85065'     '0.99664'

Additional Information related to DGs:
              Variable                                Value
    ______________________________     ______________________________________

    'DG Type'                          '3'
    'No of DGs'                        '3'
    'Location of DGs (Bus Number)'     '2   8  17'
    'Sizes of DGs in kW'               '30.5908       95.6979      177.4395'
    'Sizes of DGs in kVAR'             '119.1476       57.7806      121.1417'
    'MOI'                              '0.03176'
```

5.5.3 Comparison of Convergence Curve between SHO and ABC Algorithm:

Here is the graphical representation of Convergence Curve showing comparison between SHO and ABC algorithm.

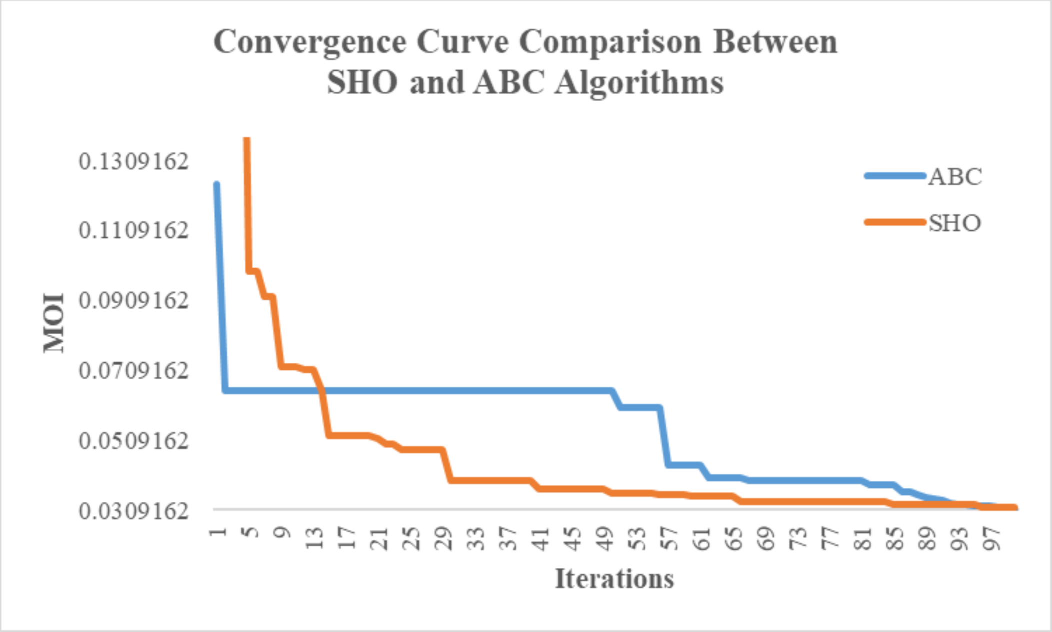


Figure 71 Convergence Curve showing comparison between SHO and ABC algorithm.

5.6 22 Bus Network System:

The network in Figure 83 depicts the Torrit visualization of the IESCO regional distributive network, comprising 20 buses and 28 branches. The total active and reactive load demand of this network is 2781 kW and 2973 kVAR respectively.

Here is the Torrit network single line diagram:

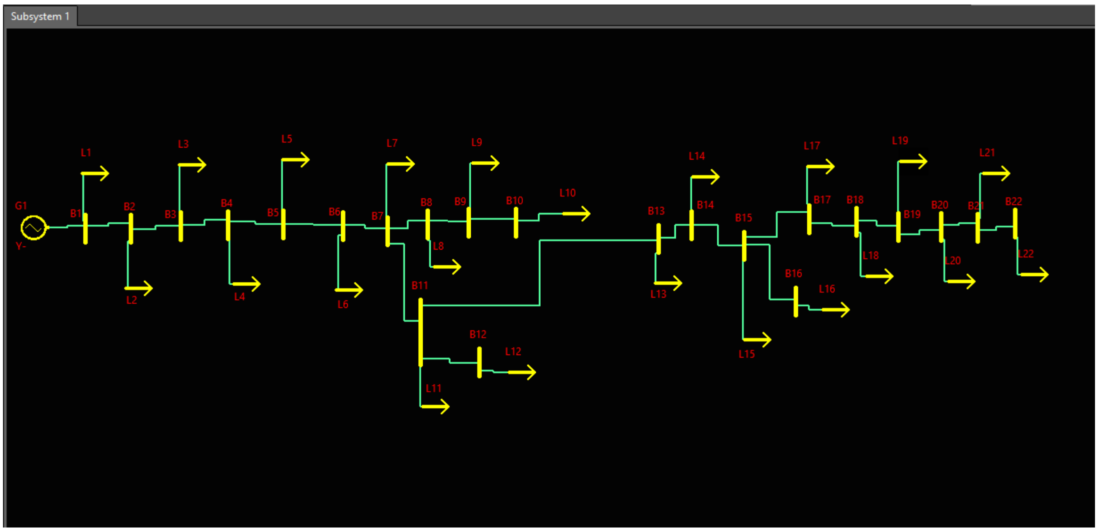


Figure 72 Torrit view of 22 Bus Network System

5.6.1 Backward Forward Sweep (BFS) Analysis of Network Using SHO Algorithm:

Below is the analysis of main parameters obtained using BFS method with SHO Algorithm:

5.6.1.1 Active Power Loss (APL) in term of DG placement:

Here is the graphical representation of Active Power Loss (APL) showing before and after placement of DGs optimally for Power factor improvement using BFS Method with SHO Algorithm

5.6.1.2 Reactive Power Loss (RPL) in term of DG placement:

Here is the graphical representation of Reactive Power Loss (RPL) showing before and after placement of DGs optimally for Power factor improvement using BFS Method with SHO Algorithm:

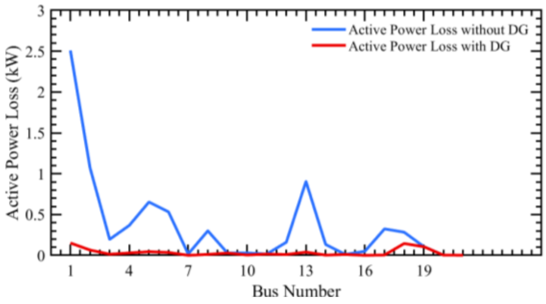


Figure 73 Active Power Loss (APL)

showing before and after placement of DGs

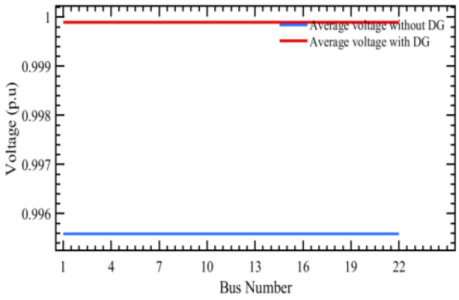


Figure 75 Average Voltage (Vavg)

showing before and after placement of DGs

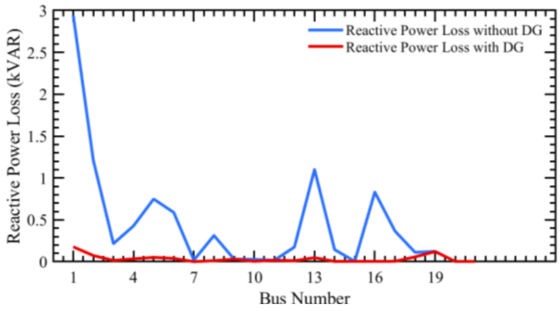


Figure 74 Reactive Power Loss (RPL)

showing before and after placement of DGs

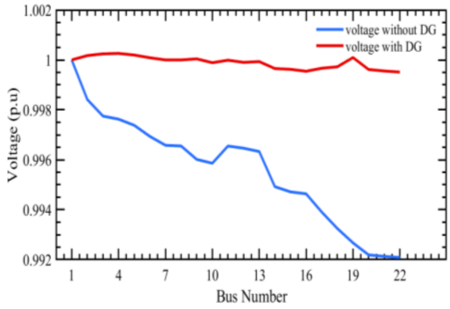


Figure 76 Minimum Voltage (Vmin)

showing before and after placement of DGs

5.6.1.3 Average Voltage (V_{avg}) in term of DG placement:

Here is the graphical representation of Average Voltage (V_{avg}) showing before and after placement of DGs optimally for Power factor improvement using BFS Method with SHO Algorithm.:

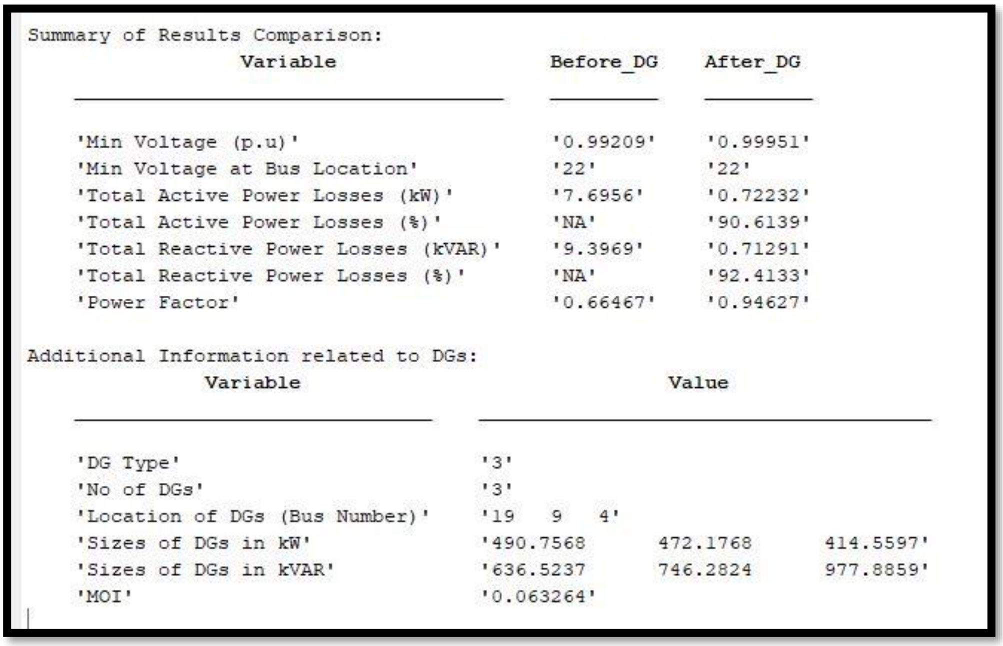
5.6.1.4 Minimum Voltage (V_{min}) in term of DG placement:

Here is the graphical representation of Minimum Voltage (V_{min}) showing before and after placement of DGs optimally for Power factor improvement using BFS Method with SHO Algorithm.:

5.6.1.5 Results Summary Using SHO Algorithm:

An outline of the efficiency benefits attained by the SHO algorithm is given in this section.

Table 18 Results Summary Using SHO Algorithm



```
Summary of Results Comparison:
                  Variable                        Before_DG     After_DG

    ____________________________________          _________     _________

    'Min Voltage (p.u)'                           '0.99209'     '0.99951'
    'Min Voltage at Bus Location'                 '22'          '22'
    'Total Active Power Losses (kW)'              '7.6956'      '0.72232'
    'Total Active Power Losses (%)'               'NA'          '90.6139'
    'Total Reactive Power Losses (kVAR)'          '9.3969'      '0.71291'
    'Total Reactive Power Losses (%)'             'NA'          '92.4133'
    'Power Factor'                                '0.66467'     '0.94627'

Additional Information related to DGs:
               Variable                                 Value

    ______________________________    ______________________________________

    'DG Type'                         '3'
    'No of DGs'                       '3'
    'Location of DGs (Bus Number)'    '19   9   4'
    'Sizes of DGs in kW'              '490.7568      472.1768      414.5597'
    'Sizes of DGs in kVAR'            '636.5237      746.2824      977.8859'
    'MOI'                             '0.063264'
```

5.6.2 Backward Forward Sweep (BFS) Analysis of Network Using ABC Algorithm:

Below is the analysis of main parameters obtained using BFS method with ABC Algorithm:

5.6.2.1 Active Power Loss (APL) in term of DG placement:

Here is the graphical representation of Active Power Loss (APL) showing before and after placement of DGs optimally for Power factor improvement using BFS Method with ABC Algorithm

5.6.2.2 Reactive Power Loss (RPL) in term of DG placement:

Here is the graphical representation of Reactive Power Loss (RPL) showing before and after placement of DGs optimally for Power factor improvement using BFS Method with ABC Algorithm.

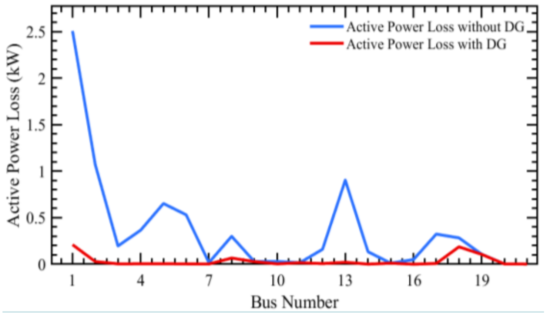


Figure 77 Active Power Loss (APL) showing before and after placement of DGs

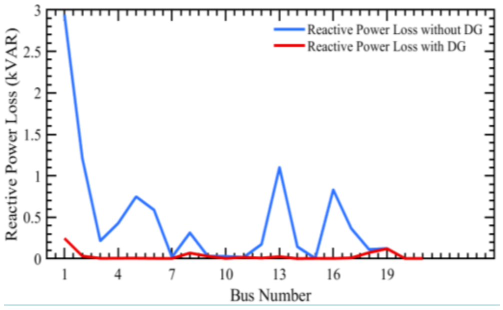


Figure 78 Reactive Power Loss (RPL) showing before and after placement of DGs

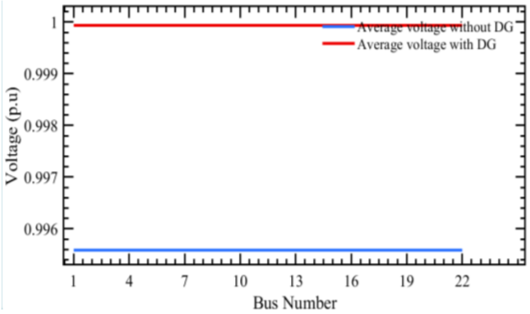


Figure 79 Average Voltage (Vavg) showing before and after placement of DGs

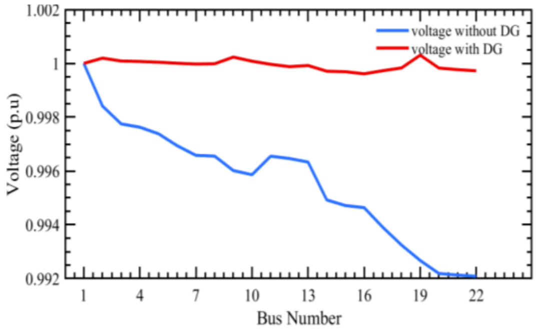


Figure 80 Minimum Voltage (Vmin) showing before and after placement of DG

5.6.2.3 Average Voltage (Vavg) in term of DG placement:

Here is the graphical representation of Average Voltage (V_{avg}) showing before and after placement of DGs optimally for Power factor improvement using BFS Method with ABC Algorithm.

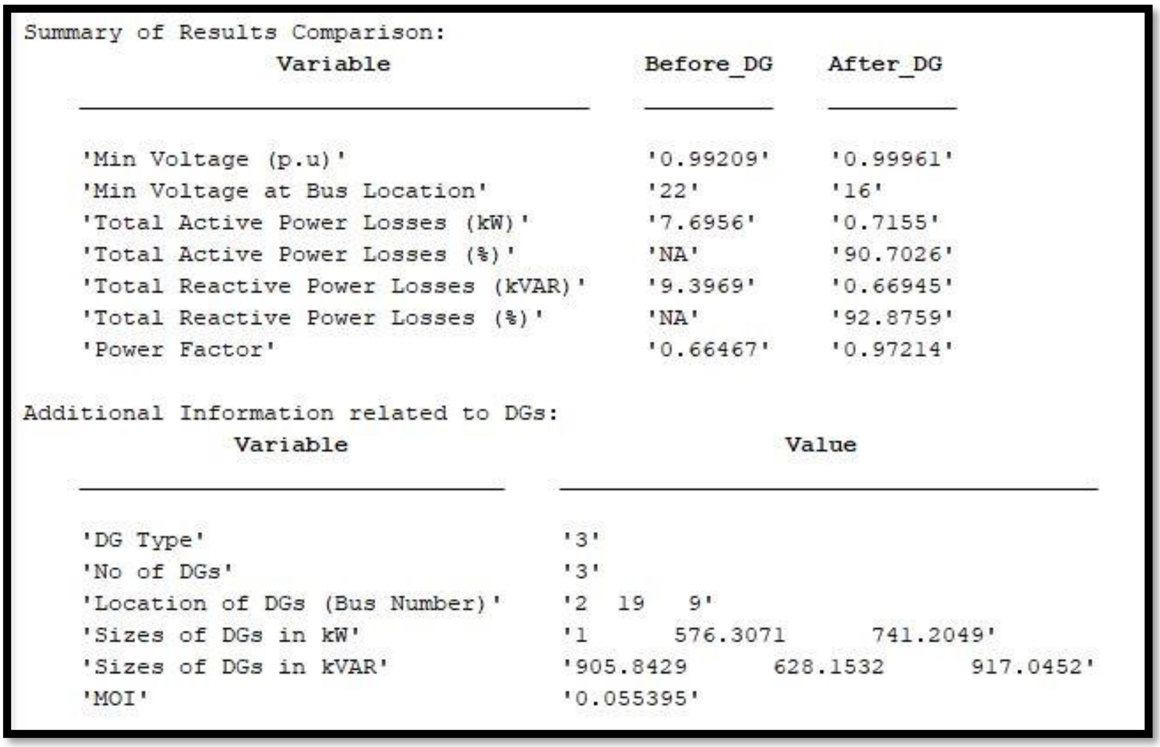
5.6.2.4 Minimum Voltage (Vmin) in term of DG placement:

Here is the graphical representation of Minimum Voltage (V_{min}) showing before and after placement of DGs optimally for Power factor improvement using BFS Method with ABC Algorithm

5.6.2.5 Results Summary Using ABC Algorithm:

The impact of DG placement are shown in the results summary using the ABC algorithm, with a focus on how it affects voltage stability and power loss reduction. A quick comparison of the ABC algorithm's performance against alternative approaches is provided in this section.

Table 19 Results Summary Using ABC Algorithm



```
Summary of Results Comparison:
                Variable                      Before_DG    After_DG
    ___________________________________      _________    _________

    'Min Voltage (p.u)'                      '0.99209'    '0.99961'
    'Min Voltage at Bus Location'            '22'         '16'
    'Total Active Power Losses (kW)'         '7.6956'     '0.7155'
    'Total Active Power Losses (%)'          'NA'         '90.7026'
    'Total Reactive Power Losses (kVAR)'     '9.3969'     '0.66945'
    'Total Reactive Power Losses (%)'        'NA'         '92.8759'
    'Power Factor'                           '0.66467'    '0.97214'

Additional Information related to DGs:
             Variable                                 Value
    _____________________________    ____________________________________

    'DG Type'                        '3'
    'No of DGs'                      '3'
    'Location of DGs (Bus Number)'   '2   19    9'
    'Sizes of DGs in kW'             '1       576.3071       741.2049'
    'Sizes of DGs in kVAR'           '905.8429      628.1532      917.0452'
    'MOI'                            '0.055395'
```

5.6.3 Comparison of Convergence Curve between SHO and ABC Algorithm:

Here is the graphical representation of Convergence Curve showing comparison between SHO and ABC algorithm

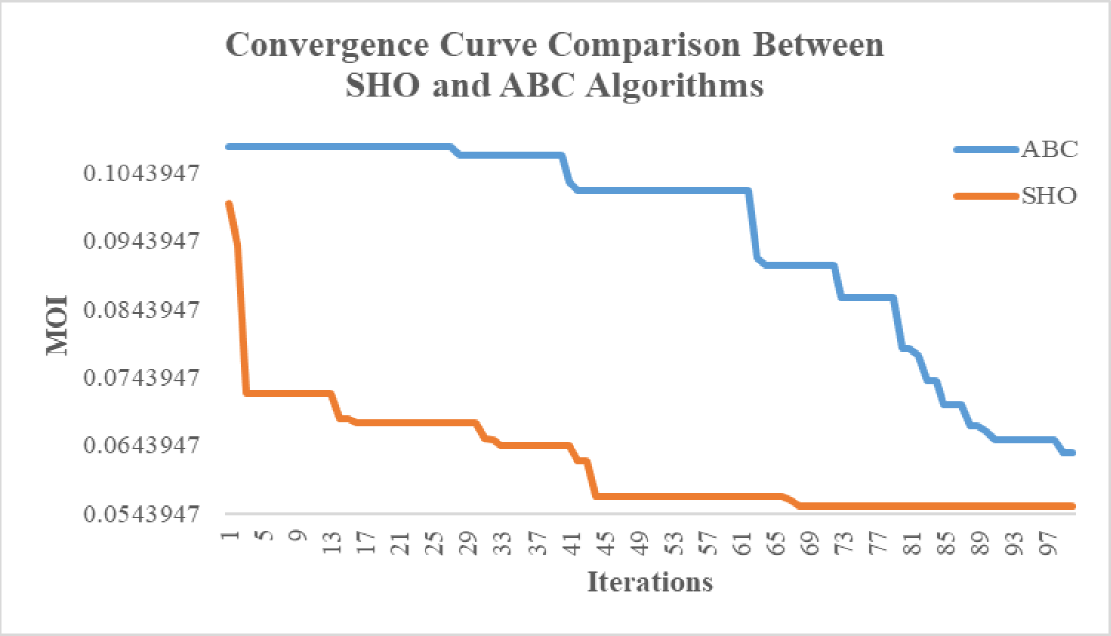


Figure 81 Convergence Curve showing comparison between SHO and ABC algorithm

5.7 26 Bus Network System:

The network in Figure 83 depicts the Torrit visualization of the IESCO regional distributive network, comprising 26 buses and 25branches. The total active and reactive load demand of this network is 3248 kW and 3692 kVAR respectively.

Here is the Torrit network single line diagram:

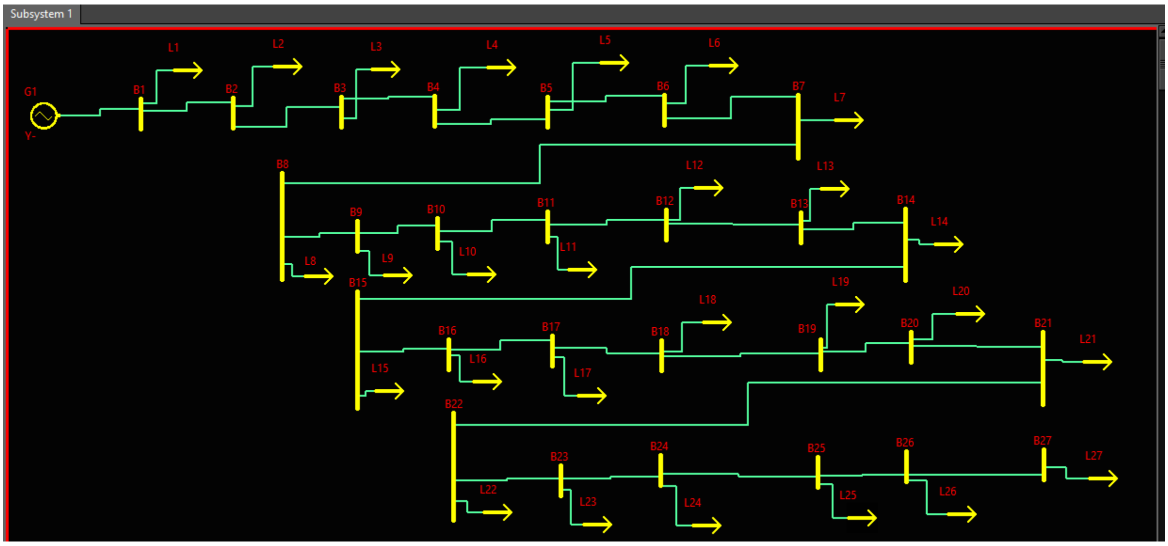


Figure 82 Torrit view of 26 Bus Network System

5.7.1 Backward Forward Sweep (BFS) Analysis of Network Using SHO Algorithm:

Below is the analysis of main parameters obtained using BFS method with SHO Algorithm:

5.7.1.1 Active Power Loss (APL) in term of DG placement:

Here is the graphical representation of Active Power Loss (APL) showing before and after placement of DGs optimally for Power factor improvement using BFS Method with SHO Algorithm

5.7.1.2 Reactive Power Loss (RPL) in term of DG placement:

Here is the graphical representation of Reactive Power Loss (RPL) showing before and after placement of DGs optimally for Power factor improvement using BFS Method with SHO Algorithm:

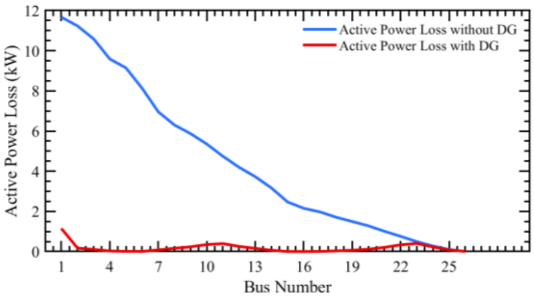


Figure 83 Active Power Loss (APL) showing before and after placement of DGs

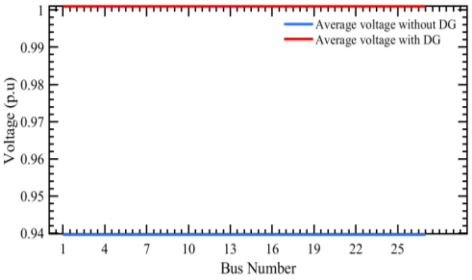


Figure 85 Average Voltage (Vavg)
showing before and after placement of DGs

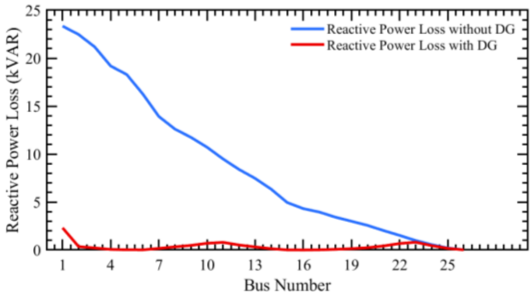


Figure 84 Reactive Power Loss (RPL) showing before and after placement of DGs

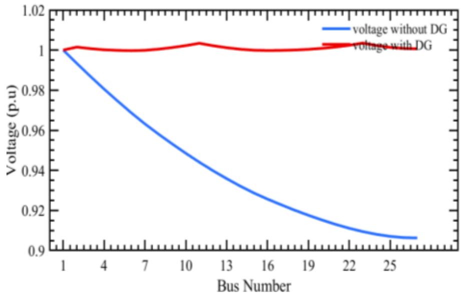


Figure 86 Minimum Voltage (Vmin)
showing before and after placement of D

5.7.1.3 Average Voltage (V_{avg}) in term of DG placement:

Here is the graphical representation of Average Voltage (V_{avg}) showing before and after placement of DGs optimally for Power factor improvement using BFS Method with SHO Algorithm.

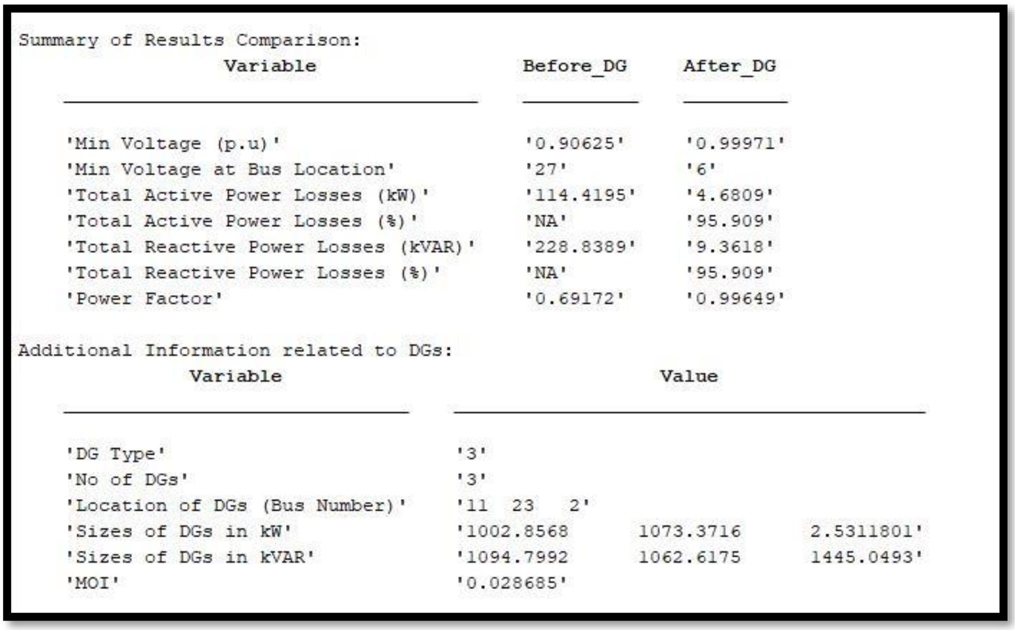
5.7.1.4 Minimum Voltage (V_{min}) in term of DG placement:

Here is the graphical representation of Minimum Voltage (V_{min}) showing before and after placement of DGs optimally for Power factor improvement using BFS Method with SHO Algorithm.

5.7.1.5 Results Summary Using SHO Algorithm:

The SHO algorithm's results summary emphasizes the Distributed Generators' (DGs) ideal placement and sizing within the network, showing improvements in voltage profiles and decreased power losses. An outline of the efficiency benefits attained by the SHO algorithm is given in this section.

Table 20 Results Summary Using SHO Algorithm



```
Summary of Results Comparison:
              Variable                  Before_DG     After_DG

    ___________________________________    __________    _________

    'Min Voltage (p.u)'                  '0.90625'     '0.99971'
    'Min Voltage at Bus Location'        '27'          '6'
    'Total Active Power Losses (kW)'     '114.4195'    '4.6809'
    'Total Active Power Losses (%)'      'NA'          '95.909'
    'Total Reactive Power Losses (kVAR)' '228.8389'    '9.3618'
    'Total Reactive Power Losses (%)'    'NA'          '95.909'
    'Power Factor'                       '0.69172'     '0.99649'

Additional Information related to DGs:
           Variable                              Value

    _____________________________    ________________________________________

    'DG Type'                        '3'
    'No of DGs'                      '3'
    'Location of DGs (Bus Number)'   '11  23   2'
    'Sizes of DGs in kW'             '1002.8568      1073.3716      2.5311801'
    'Sizes of DGs in kVAR'           '1094.7992      1062.6175      1445.0493'
    'MOI'                            '0.028685'
```

5.7.2 Backward Forward Sweep (BFS) Analysis of Network Using ABC Algorithm:

Below is the analysis of main parameters obtained using BFS method with ABC Algorithm:

5.7.2.1 Active Power Loss (APL) in term of DG placement:

Here is the graphical representation of Active Power Loss (APL) showing before and after placement of DGs optimally for Power factor improvement using BFS Method with ABC Algorithm.

5.7.2.2 Reactive Power Loss (RPL) in term of DG placement:

Here is the graphical representation of Reactive Power Loss (RPL) showing before and after placement of DGs optimally for Power factor improvement using BFS Method with ABC Algorithm.

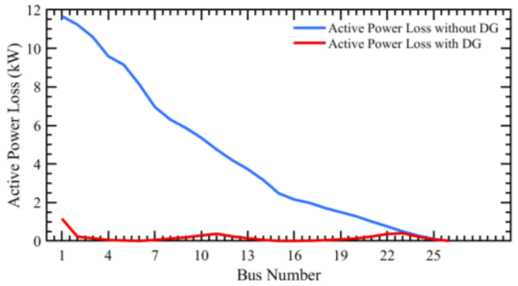


Figure 87 Active Power Loss (APL) showing before and after placement of DGs

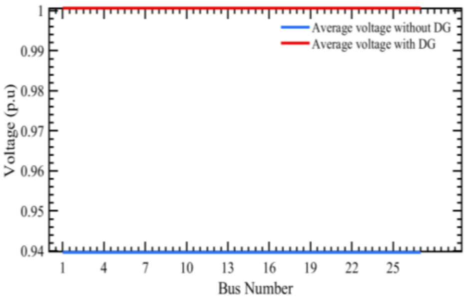


Figure 89 Average Voltage (Vavg) showing before and after placement of DGs

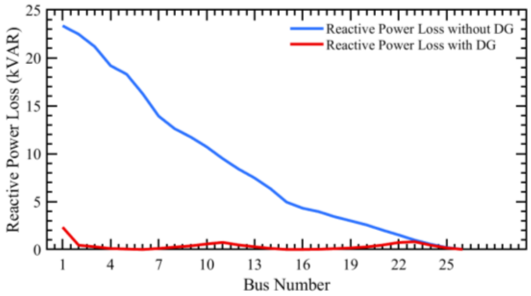


Figure 88 Reactive Power Loss (RPL) showing before and after placement of DGs

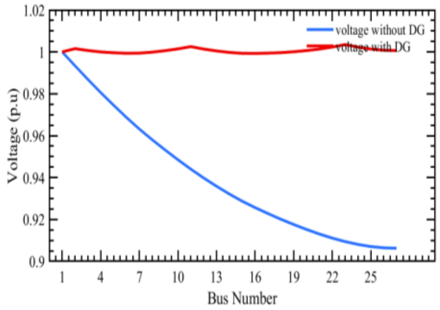


Figure 90 Minimum Voltage (Vmin) showing before and after placement of DGs

5.7.2.3 Average Voltage (Vavg) in term of DG placement:

Here is the graphical representation of Average Voltage (V_{avg}) showing before and after placement of DGs optimally for Power factor improvement using BFS Method with ABC Algorithm.:

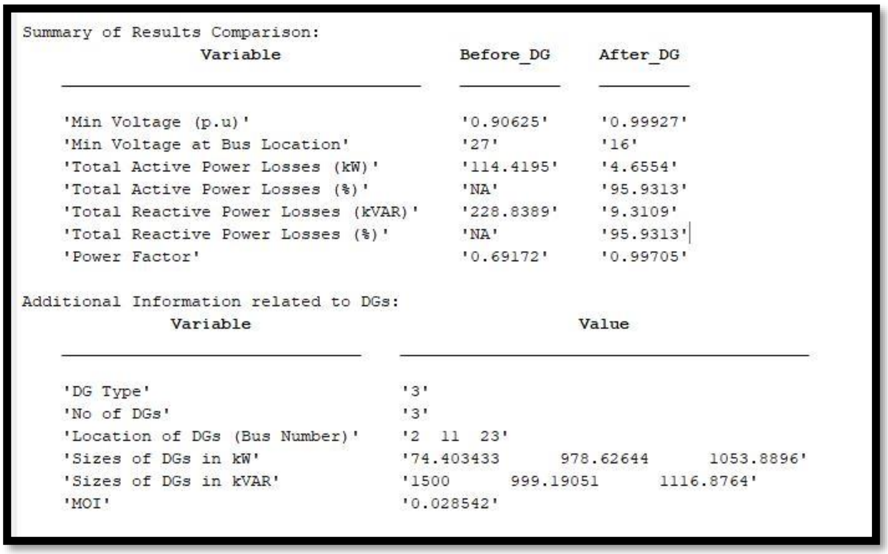
5.7.2.4 Minimum Voltage (Vmin) in term of DG placement:

Here is the graphical representation of Minimum Voltage (V_{min}) showing before and after placement of DGs optimally for Power factor improvement using BFS Method with ABC Algorithm.:

5.7.2.5 Results Summary Using ABC Algorithm:

The effects of DG location are illustrated in the findings summary of the ABC algorithm, with a focus on how they affect voltage stability and power loss reduction. A quick comparison of the ABC algorithm's performance with alternative approaches is given in this section.

Table 21 Results Summary Using ABC Algorithm



```
Summary of Results Comparison:
                  Variable                            Before_DG      After_DG

    ____________________________________            __________     _________

    'Min Voltage (p.u)'                             '0.90625'      '0.99927'
    'Min Voltage at Bus Location'                   '27'           '16'
    'Total Active Power Losses (kW)'                '114.4195'     '4.6554'
    'Total Active Power Losses (%)'                 'NA'           '95.9313'
    'Total Reactive Power Losses (kVAR)'            '228.8389'     '9.3109'
    'Total Reactive Power Losses (%)'               'NA'           '95.9313'
    'Power Factor'                                  '0.69172'      '0.99705'

Additional Information related to DGs:
               Variable                                        Value

    ______________________________        _________________________________________

    'DG Type'                             '3'
    'No of DGs'                           '3'
    'Location of DGs (Bus Number)'        '2   11   23'
    'Sizes of DGs in kW'                  '74.403433       978.62644       1053.8896'
    'Sizes of DGs in kVAR'                '1500       999.19051       1116.8764'
    'MOI'                                 '0.028542'
```

5.7.3 Comparison of Convergence Curve between SHO and ABC Algorithm:

Here is the graphical representation of Convergence Curve showing comparison between SHO and ABC algorithm

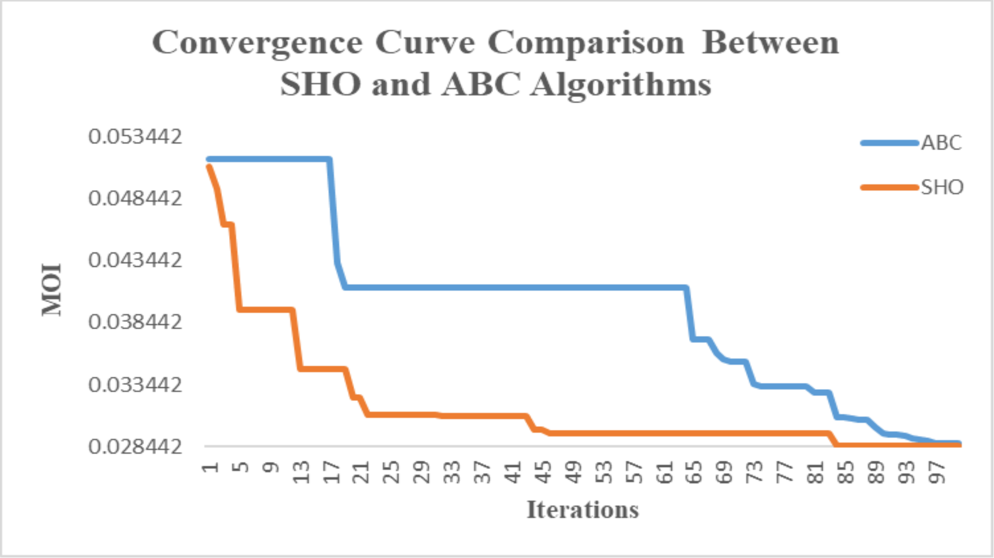


Figure 91 Convergence Curve showing comparison between SHO and ABC algorithm

5.8 Overall Result Comparison between Algorithms

The Sea Horse Optimization (SHO) and Artificial Bee Colony (ABC) algorithms' performances in various network architectures are contrasted in the table. It assesses important parameters before to and during the deployment of Distributed Generators (DGs), including minimum voltage, total active and reactive power losses, and power factor. The outcomes demonstrate how each tactic improved voltage stability, decreased power loss, and increased power factor. The comparison makes clear the relative benefits of the SHO and ABC algorithms for various distribution network optimization scenarios.

Table 22 Overall Result Comparison between Algorithms

Network	**Algorithm**	**Variable**	**Before DG**	**After DG**	**% Improvement**
IEEE 33 Bus	**SHO**	Min Voltage (p.u)	0.91309	0.9922	8.68%
		Total Active Power Losses (kW)	202.6771	18.3194	90.96%
		Total Reactive Power Losses (kVAR)	135.141	13.8962	89.72%
		Power Factor	0.8493	0.94739	11.56%
	ABC	Min Voltage (p.u)	0.91309	0.99218	8.68%
		Total Active Power Losses (kW)	202.6771	15.0378	92.58%
		Total Reactive Power Losses (kVAR)	135.141	11.585	91.43%
		Power Factor	0.8493	0.93222	9.77%

IEEE 69 Bus	**SHO**	Min Voltage (p.u)	0.99999	1	0.01%
		Total Active Power Losses (kW)	1.19E-05	1.76E-07	99.85%
		Total Reactive Power Losses (kVAR)	1.55E-06	5.84E-07	62.68%
		Power Factor	0.81587	0.99982	22.58%
	ABC	Min Voltage (p.u)	0.99999	1	0.01%
		Total Active Power Losses (kW)	1.19E-05	1.38E-06	88.42%
		Total Reactive Power Losses (kVAR)	1.55E-06	1.83E-07	88.17%
		Power Factor	0.81587	0.95267	16.73%
15 Bus	**SHO**	Min Voltage (p.u)	0.99723	0.99993	0.27%
		Total Active Power Losses (kW)	2.2983	0.15257	93.36%
		Total Reactive Power Losses (kVAR)	2.6098	0.17214	93.35%
		Power Factor	0.66482	0.96981	45.78%
	ABC	Min Voltage (p.u)	0.99723	0.99995	0.28%
		Total Active Power Losses (kW)	2.2983	0.13846	93.98%
		Total Reactive Power Losses (kVAR)	2.6098	0.15922	93.89%
		Power Factor	0.66482	0.98211	47.59%

18 Bus	**SHO**	Min Voltage (p.u)	0.96	0.99386	3.53%
		Total Active Power Losses (kW)	47.6148	5.9532	87.50%
		Total Reactive Power Losses (kVAR)	44.4792	4.71	89.43%
		Power Factor	0.70231	0.96926	38.07%
	ABC	Min Voltage (p.u)	0.96	0.99472	3.61%
		Total Active Power Losses (kW)	47.6148	5.8931	87.62%
		Total Reactive Power Losses (kVAR)	44.4792	4.6144	89.65%
		Power Factor	0.70231	0.95954	36.58%
20 Bus	**SHO**	Min Voltage (p.u)	0.99953	0.99999	0.05%
		Total Active Power Losses (kW)	0.048605	0.0021351	95.63%
		Total Reactive Power Losses (kVAR)	0.16288	0.0081101	95.02%
		Power Factor	0.85065	0.99919	17.45%
	ABC	Min Voltage (p.u)	0.99953	1	0.05%
		Total Active Power Losses (kW)	0.048605	0.0021558	95.58%
		Total Reactive Power Losses (kVAR)	0.16288	0.0081778	95.02%
		Power Factor	0.85065	0.99664	17.23%

22 Bus	**SHO**	Min Voltage (p.u)	0.99209	0.99951	0.74%
		Total Active Power Losses (kW)	7.6956	0.72232	90.63%
		Total Reactive Power Losses (kVAR)	19.3969	0.71291	96.32%
		Power Factor	0.66467	0.94627	42.41%
	ABC	Min Voltage (p.u)	0.99209	0.99961	0.75%
		Total Active Power Losses (kW)	7.6956	0.7155	90.71%
		Total Reactive Power Losses (kVAR)	19.3969	0.66945	96.55%
		Power Factor	0.66467	0.97214	46.09%
26 Bus	**SHO**	Min Voltage (p.u)	0.90625	0.99971	10.30%
		Total Active Power Losses (kW)	27	6	77.78%
		Total Reactive Power Losses (kVAR)	NA	228.8389	NA
		Power Factor	0.69172	0.99649	44.24%
	ABC	Min Voltage (p.u)	0.90625	0.99927	10.28%
		Total Active Power Losses (kW)	27	16	40.74%
		Total Reactive Power Losses (kVAR)	NA	297.4579	NA
		Power Factor	0.69172	0.99752	44.24%

5.8.1 Visualization of results comparison with SHO Algorithm:

Figure 91 shows the impact of Distributed Generation (DG) deployment using the SHO (Sea Horse Optimization) algorithm on several network performance metrics. Among the many network types that are explored are many IESCO networks, IEEE 33-Bus, and IEEE 69-Bus.

Plots showing statistics on network performance before and after DG installation are included. Among these measurements are Power Factor, Total Active Power Losses (kW), Total Reactive Power Losses (VAR), and Min Voltage (p.u.). These measures are optimized using the SHO approach, and the results are displayed using two different colors: red for conditions after DG installation and dark blue for conditions before DG installation.

Solid lines represent measures after DG installation, while dotted lines represent metrics before DG installation.

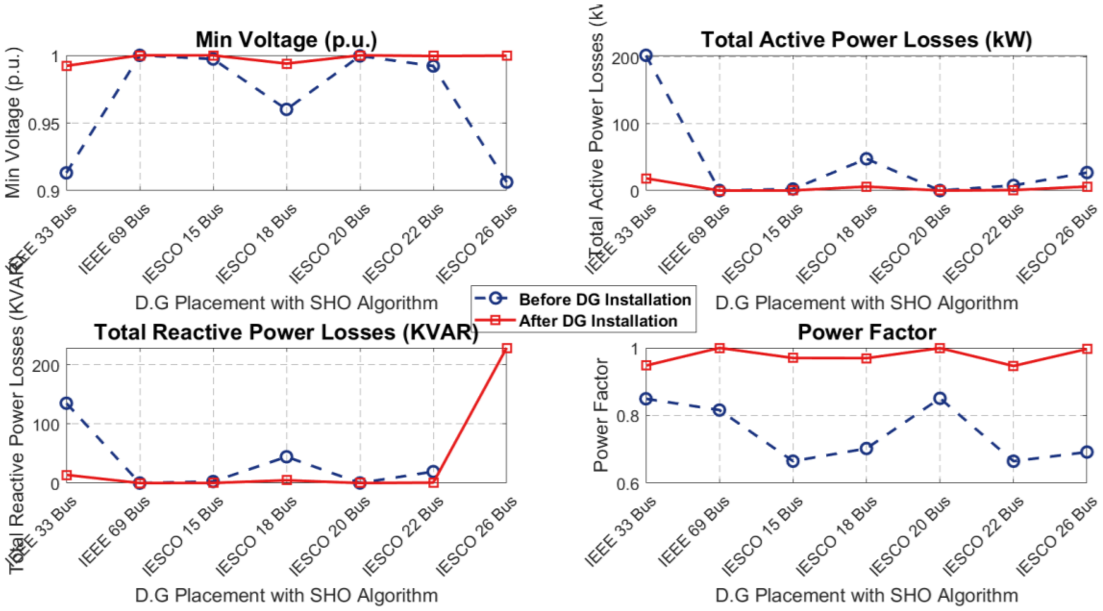


Figure 92 Visualization of results comparison with SHO Algorithm

This professional presentation highlights the effectiveness of the SHO algorithm in improving network performance through DG placement, offering a clear visual comparison of the enhancements achieved

5.8.2 Visualization of results comparison with ABC Algorithm:

The Graphs depicting the performance indicators of the ABC Algorithm before and after Distributed Generators (DGs) were integrated across various networks are shown in Figure 93. Power factor, total active and reactive power losses, and minimum voltage levels are among the important indicators that are shown. Red data is collected after DG deployment, and dark blue data is collected prior to DG placement. These visualizations allow one to assess the effectiveness of the ABC Algorithm in optimizing network performance with and without DGs. The graphs show how the integration of DGs has enhanced voltage stability, reduced power losses, and raised power factor through the examination of various metrics.

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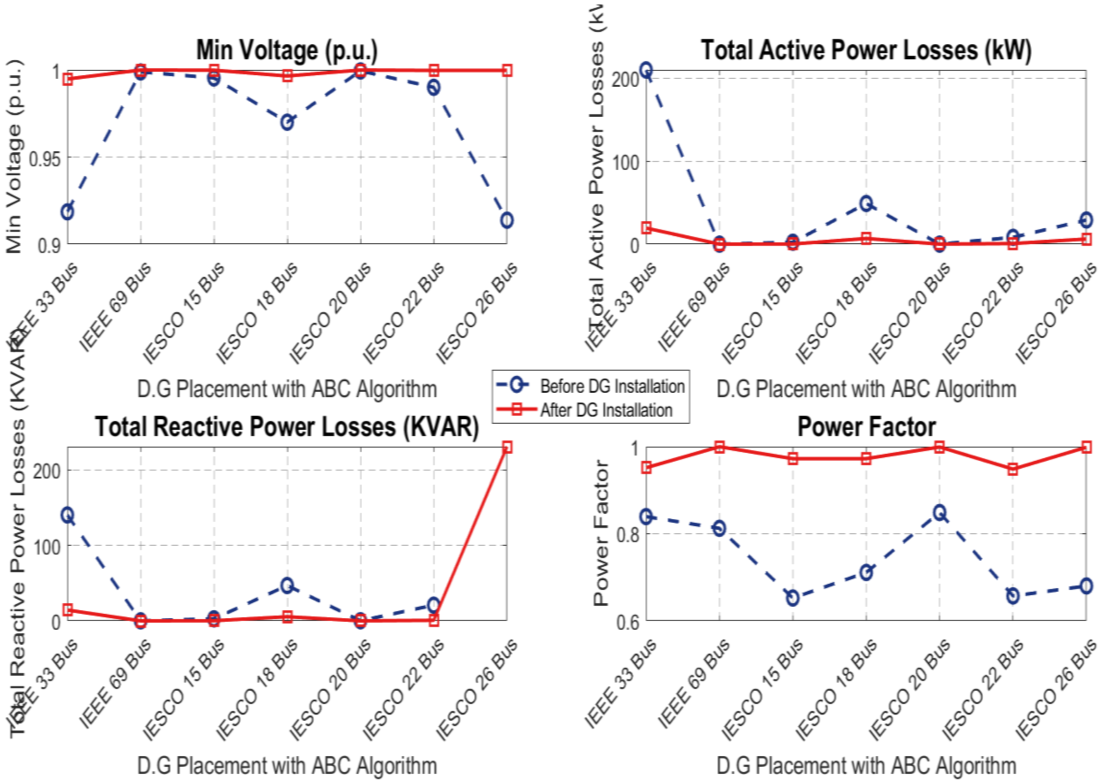

Figure 93 Visualization of results comparison with ABC Algorithm

5.8.3 Comparison between performance of Both Algorithms:

Based on the research, the following is a quick comparison of how well the SHO and ABC algorithms performed:

Table 23 Comparison between performance of Both Algorithms

Metric	SHO Algorithm	ABC Algorithm
Voltage Levels	Shows a clear increase in voltage levels with DGs in every network, indicating improved stability.	Exhibits a noticeable increase in voltage levels with DGs, though slightly less than SHO.
Active Power Losses	Significant reduction in active power losses with DG placement, indicating better power distribution efficiency.	Reduction in active power losses is observed, but the improvement is less pronounced compared to SHO.
Reactive Power Losses	Major decrease in reactive power losses post-DG placement, showing effective power factor correction.	Decrease in reactive power losses is evident, but the reduction is not as significant as with SHO.
Power Factor	With the addition of DG, power factor considerably increased, increasing system efficiency	The power factor improvement is not as significant as the one obtained with SHO, however it is still noticeable

Chapter 6

Conclusion and Future Work

6 CONCLUSION AND FUTURE WORK

6.1 Conclusion

This study concludes by offering a thorough analysis of various Distributed Generator (DG) types and their effects on distribution networks' power factor enhancement and reduction. The study successfully evaluated the performance of various distributed generator (DG) types and showed how, by utilizing the Sea Horse Optimization (SHO) algorithm and the Backward Forward Sweep Method (BFSM), they increase network efficiency.

An extensive investigation of IESCO regional networks and IEEE 33- and 69-bus systems validates the efficacy of the suggested solutions. Utility operators may optimize power system performance, maximize efficiency, and make informed decisions about power distribution management by utilizing the solid basis provided by this study. Utility operators can utilize these data to make informed decisions on the deployment of distributed generation (DGs). Depending on the particular requirements of the network, the type of distributed generation (DG) that is selected may have the impact of lowering power losses, increasing power factor, or striking a compromise between the two. Distribution network management techniques become more tailored and efficient as a result of this flexibility.

6.2 Future Work

Future work includes:

- Electric Vehicles (EVs) can be integrated in this framework.
- Utilization of Machine Learning techniques.
- The probabilistic Nature of Wind and Solar DGs can be incorporated to carry out probabilistic load flow.
- The objectives of economic analysis of DGs can also be taken into account.

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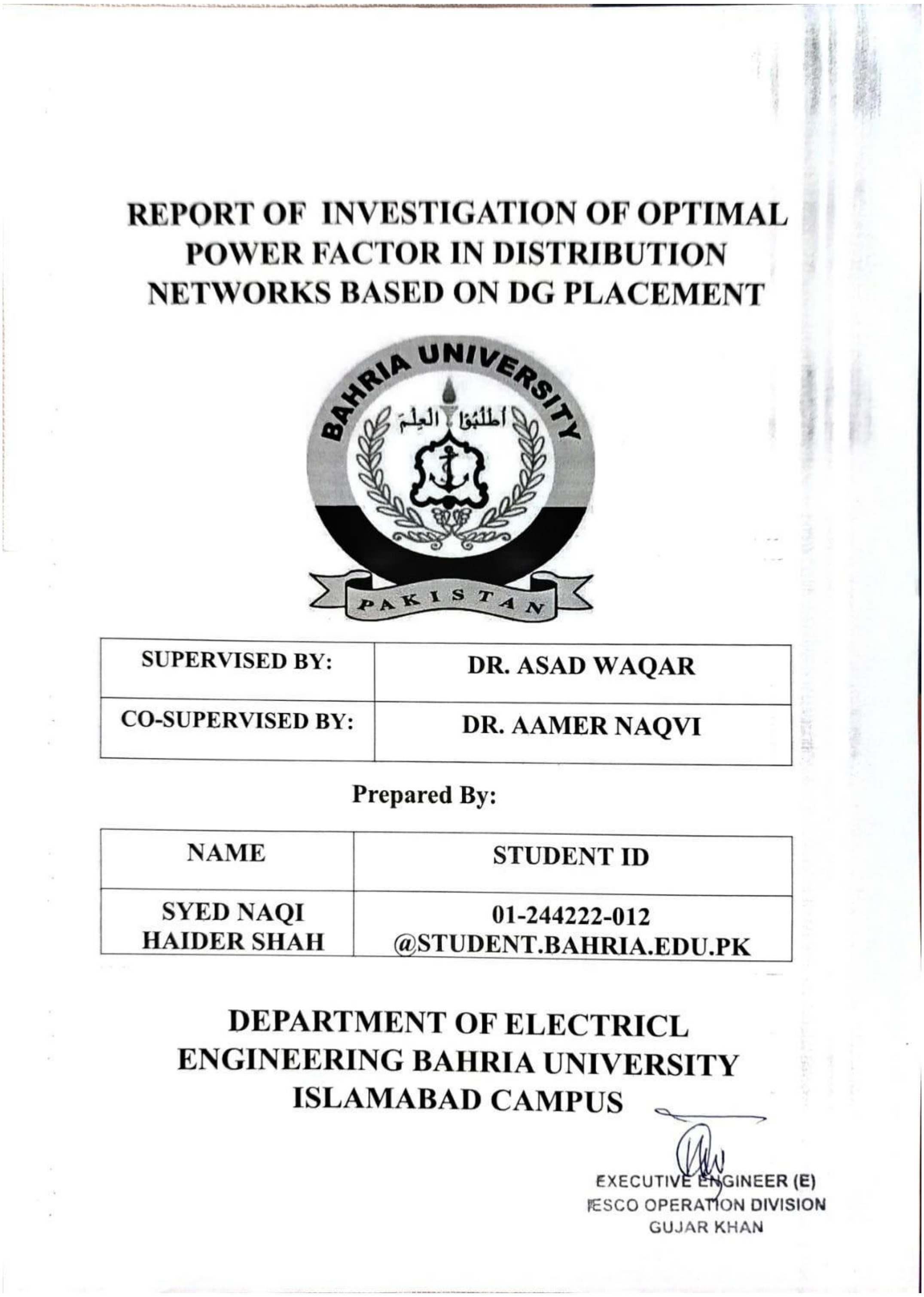
7 ANNEXURE

Attested Report for Data validation from IESCO Operation Department:



REPORT OF INVESTIGATION OF OPTIMAL POWER FACTOR IN DISTRIBUTION NETWORKS BASED ON DG PLACEMENT

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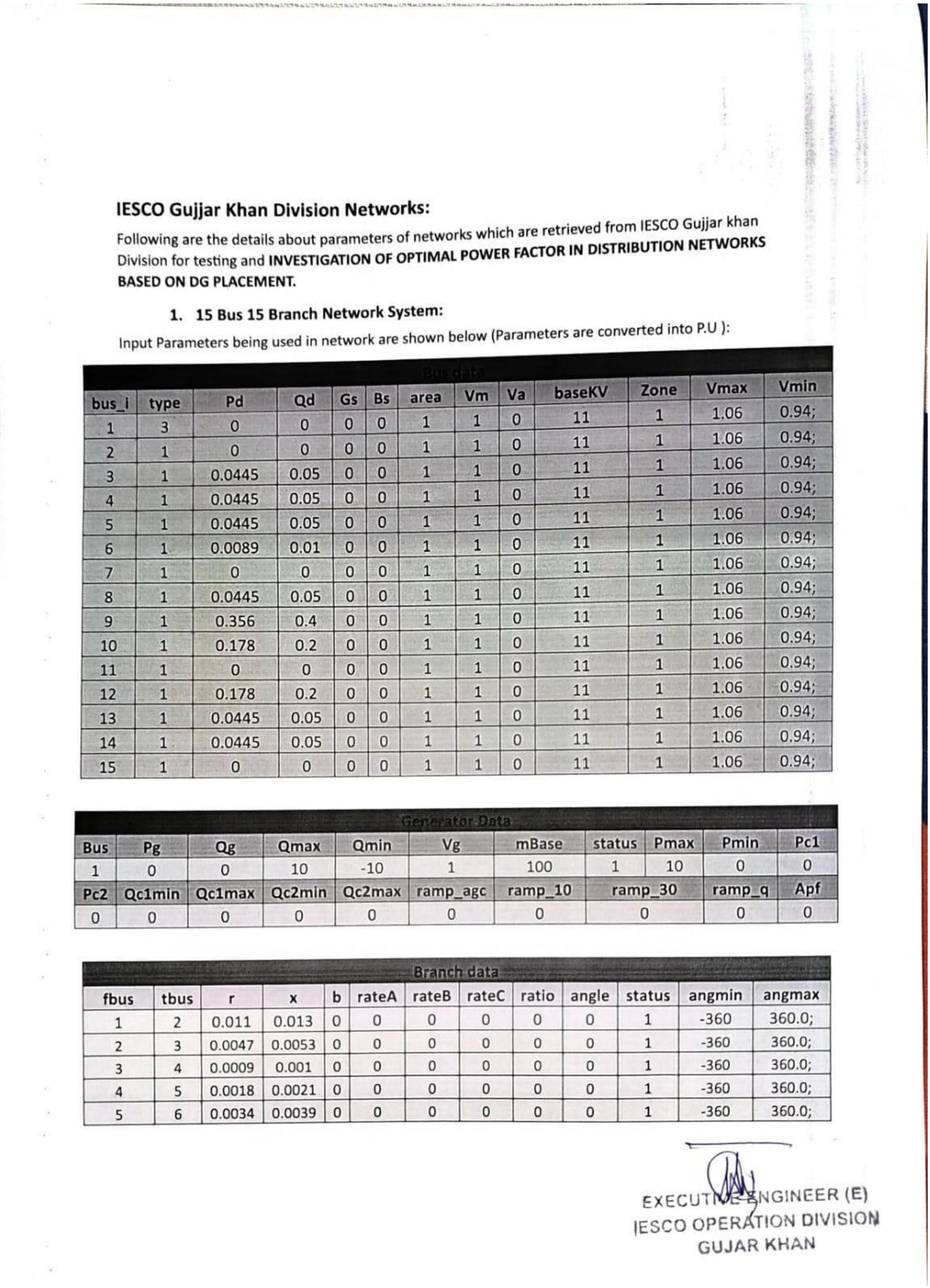

IESCO Gujjar Khan Division Networks:

Following are the details about parameters of networks which are retrieved from IESCO Gujjar khan Division for testing and **INVESTIGATION OF OPTIMAL POWER FACTOR IN DISTRIBUTION NETWORKS BASED ON DG PLACEMENT.**

1. 15 Bus 15 Branch Network System:

Input Parameters being used in network are shown below (Parameters are converted into P.U):

Bus data

bus_i	type	Pd	Qd	Gs	Bs	area	Vm	Va	baseKV	Zone	Vmax	Vmin
1	3	0	0	0	0	1	1	0	11	1	1.06	0.94;
2	1	0	0	0	0	1	1	0	11	1	1.06	0.94;
3	1	0.0445	0.05	0	0	1	1	0	11	1	1.06	0.94;
4	1	0.0445	0.05	0	0	1	1	0	11	1	1.06	0.94;
5	1	0.0445	0.05	0	0	1	1	0	11	1	1.06	0.94;
6	1	0.0089	0.01	0	0	1	1	0	11	1	1.06	0.94;
7	1	0	0	0	0	1	1	0	11	1	1.06	0.94;
8	1	0.0445	0.05	0	0	1	1	0	11	1	1.06	0.94;
9	1	0.356	0.4	0	0	1	1	0	11	1	1.06	0.94;
10	1	0.178	0.2	0	0	1	1	0	11	1	1.06	0.94;
11	1	0	0	0	0	1	1	0	11	1	1.06	0.94;
12	1	0.178	0.2	0	0	1	1	0	11	1	1.06	0.94;
13	1	0.0445	0.05	0	0	1	1	0	11	1	1.06	0.94;
14	1	0.0445	0.05	0	0	1	1	0	11	1	1.06	0.94;
15	1	0	0	0	0	1	1	0	11	1	1.06	0.94;

Generator Data

Bus	Pg	Qg	Qmax	Qmin	Vg	mBase	status	Pmax	Pmin	Pc1
1	0	0	10	-10	1	100	1	10	0	0
Pc2	**Qc1min**	**Qc1max**	**Qc2min**	**Qc2max**	**ramp_agc**	**ramp_10**	**ramp_30**		**ramp_q**	**Apf**
0	0	0	0	0	0	0	0		0	0

Branch data

fbus	tbus	r	x	b	rateA	rateB	rateC	ratio	angle	status	angmin	angmax
1	2	0.011	0.013	0	0	0	0	0	0	1	-360	360.0;
2	3	0.0047	0.0053	0	0	0	0	0	0	1	-360	360.0;
3	4	0.0009	0.001	0	0	0	0	0	0	1	-360	360.0;
4	5	0.0018	0.0021	0	0	0	0	0	0	1	-360	360.0;
5	6	0.0034	0.0039	0	0	0	0	0	0	1	-360	360.0;

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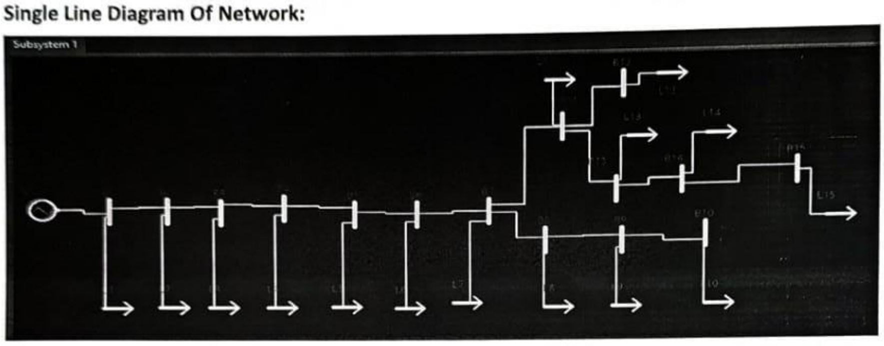
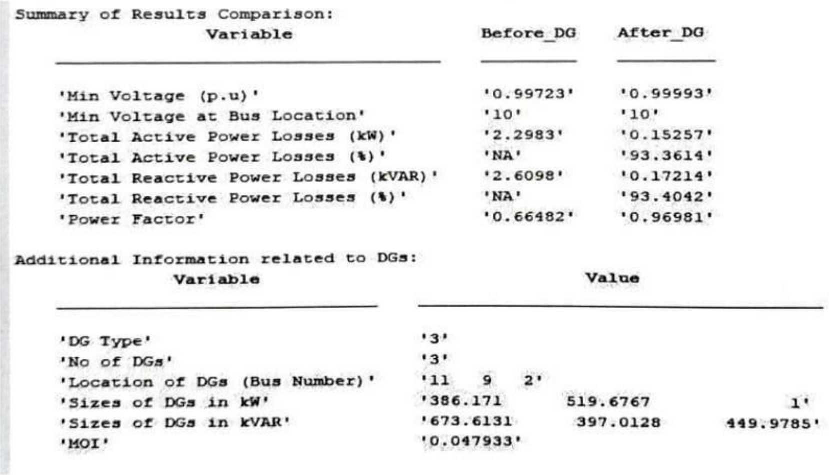
6	7	0.0028	0.0031	0	0	0	0	0	0	1	-360	360.0;
7	8	0.0006	0.0006	0	0	0	0	0	0	1	-360	360.0;
8	9	0.012	0.0125	0	0	0	0	0	0	1	-360	360.0;
9	10	0.01	0.011	0	0	0	0	0	0	1	-360	360.0;
7	11	0.0004	0.0004	0	0	0	0	0	0	1	-360	360.0;
11	12	0.0057	0.0062	0	0	0	0	0	0	1	-360	360.0;
11	13	0.0036	0.0039	0	0	0	0	0	0	1	-360	360.0;
13	14	0.023	0.028	0	0	0	0	0	0	1	-360	360.0;
14	15	0.0039	0.0042	0	0	0	0	0	0	1	-360	360.0;

Single Line Diagram Of Network:



Results Summary Comparison Before & After D.G Placement:

1. **Results obtained from SEA HORSE OPTIMIZATION Algorithm:**



```
Summary of Results Comparison:
                  Variable                          Before_DG      After_DG
     ________________________________________      _________      _________

     'Min Voltage (p.u)'                            '0.99723'      '0.99993'
     'Min Voltage at Bus Location'                  '10'           '10'
     'Total Active Power Losses (kW)'               '2.2983'       '0.15257'
     'Total Active Power Losses (%)'                'NA'           '93.3614'
     'Total Reactive Power Losses (kVAR)'           '2.6098'       '0.17214'
     'Total Reactive Power Losses (%)'              'NA'           '93.4042'
     'Power Factor'                                 '0.66482'      '0.96981'

Additional Information related to DGs:
               Variable                                  Value
     _________________________________    _______________________________________

     'DG Type'                            '3'
     'No of DGs'                          '3'
     'Location of DGs (Bus Number)'       '11    9    2'
     'Sizes of DGs in kW'                 '386.171         519.6767              1'
     'Sizes of DGs in kVAR'               '673.6131         397.0128       449.9785'
     'MOI'                                '0.047933'
```

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2. Results obtained from ARTIFICIAL BEE COLONY Algorithm:

```
Summary of Results Comparison:
                  Variable                        Before_DG     After_DG
     ____________________________________        _________     _________

     'Min Voltage (p.u)'                          '0.99723'     '0.99995'
     'Min Voltage at Bus Location'                '10'          '14'
     'Total Active Power Losses (kW)'             '2.2983'      '0.13846'
     'Total Active Power Losses (%)'              'NA'          '93.9755'
     'Total Reactive Power Losses (kVAR)'         '2.6098'      '0.15922'
     'Total Reactive Power Losses (%)'            'NA'          '93.8993'
     'Power Factor'                               '0.66482'     '0.98211'

Additional Information related to DGs:
               Variable                                  Value
     ________________________________    ______________________________________

     'DG Type'                           '3'
     'No of DGs'                         '3'
     'Location of DGs (Bus Number)'      '9    2   12'
     'Sizes of DGs in kW'                '590.2673        40.152        228.7612'
     'Sizes of DGs in kVAR'              '650.629       596.8152        298.3533'
     'MOI'                               '0.04208'
```

2. 18 Bus 17 Branch Network System:

Parameters are entered in their own units as Pd and Qd are specified in kW & kVAr. Also r and x specified in ohms here. Code will Automatically Convert them into P.U before burning

Bus data

bus_i	type	Pd	Qd	Gs	Bs	area	Vm	Va	baseKV	zone	Vmax	Vmin
1	3	0	0	0	0	1	1	0	11	1	1	1;
2	1	43.5	45.5	0	0	1	1	0	11	1	1.1	0.9;
3	1	71.5	72.5	0	0	1	1	0	11	1	1.1	0.9;
4	1	140.5	142	0	0	1	1	0	11	1	1.1	0.9;
5	1	45	46	0	0	1	1	0	11	1	1.1	0.9;
6	1	140.5	142	0	0	1	1	0	11	1	1.1	0.9;
7	1	139.5	141.5	0	0	1	1	0	11	1	1.1	0.9;
8	1	71	72	0	0	1	1	0	11	1	1.1	0.9;
9	1	69.5	71	0	0	1	1	0	11	1	1.1	0.9;
10	1	43	44	0	0	1	1	0	11	1	1.1	0.9;
11	1	139	141	0	0	1	1	0	11	1	1.1	0.9;

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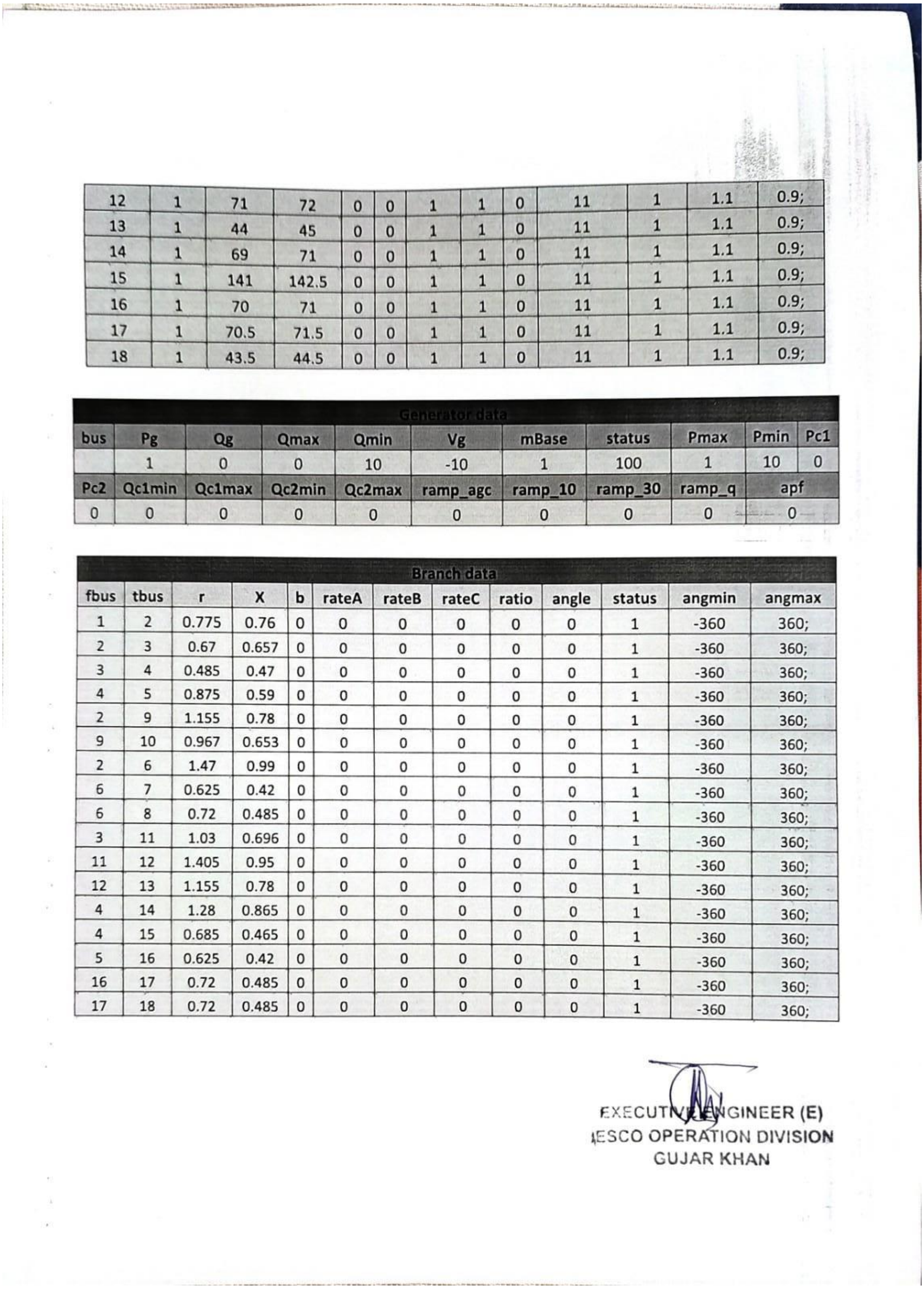

12	1	71	72	0	0	1	1	0	11	1	1.1	0.9;
13	1	44	45	0	0	1	1	0	11	1	1.1	0.9;
14	1	69	71	0	0	1	1	0	11	1	1.1	0.9;
15	1	141	142.5	0	0	1	1	0	11	1	1.1	0.9;
16	1	70	71	0	0	1	1	0	11	1	1.1	0.9;
17	1	70.5	71.5	0	0	1	1	0	11	1	1.1	0.9;
18	1	43.5	44.5	0	0	1	1	0	11	1	1.1	0.9;

Generator data

bus	Pg	Qg	Qmax	Qmin	Vg	mBase	status	Pmax	Pmin	Pc1
	1	0	0	10	-10	1	100	1	10	0
Pc2	**Qc1min**	**Qc1max**	**Qc2min**	**Qc2max**	**ramp_agc**	**ramp_10**	**ramp_30**	**ramp_q**	**apf**	
0	0	0	0	0	0	0	0	0	0	

Branch data

fbus	tbus	r	X	b	rateA	rateB	rateC	ratio	angle	status	angmin	angmax
1	2	0.775	0.76	0	0	0	0	0	0	1	-360	360;
2	3	0.67	0.657	0	0	0	0	0	0	1	-360	360;
3	4	0.485	0.47	0	0	0	0	0	0	1	-360	360;
4	5	0.875	0.59	0	0	0	0	0	0	1	-360	360;
2	9	1.155	0.78	0	0	0	0	0	0	1	-360	360;
9	10	0.967	0.653	0	0	0	0	0	0	1	-360	360;
2	6	1.47	0.99	0	0	0	0	0	0	1	-360	360;
6	7	0.625	0.42	0	0	0	0	0	0	1	-360	360;
6	8	0.72	0.485	0	0	0	0	0	0	1	-360	360;
3	11	1.03	0.696	0	0	0	0	0	0	1	-360	360;
11	12	1.405	0.95	0	0	0	0	0	0	1	-360	360;
12	13	1.155	0.78	0	0	0	0	0	0	1	-360	360;
4	14	1.28	0.865	0	0	0	0	0	0	1	-360	360;
4	15	0.685	0.465	0	0	0	0	0	0	1	-360	360;
5	16	0.625	0.42	0	0	0	0	0	0	1	-360	360;
16	17	0.72	0.485	0	0	0	0	0	0	1	-360	360;
17	18	0.72	0.485	0	0	0	0	0	0	1	-360	360;

EXECUTIVE ENGINEER (E)
IESCO OPERATION DIVISION
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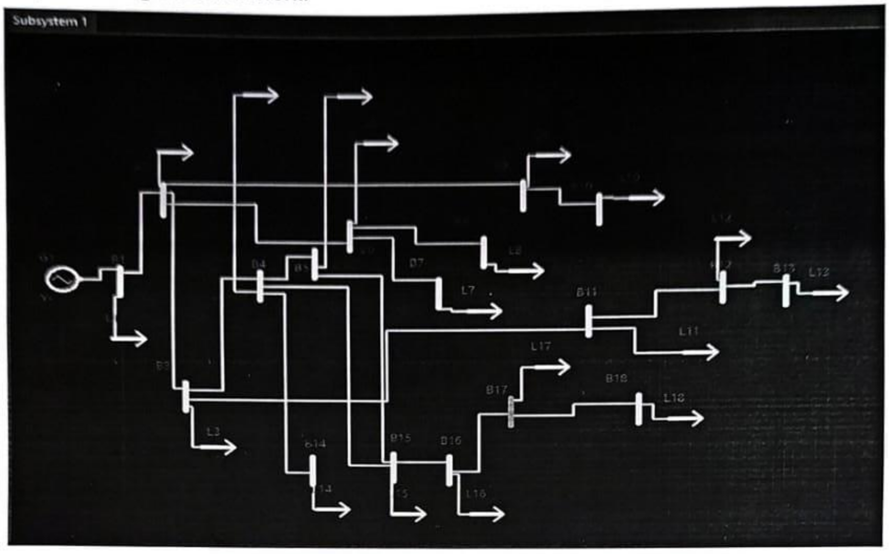
Single Line Diagram Of Network:



Results Summary Comparison Before & After D.G Placement:

1. **Results obtained from SEA HORSE OPTIMIZATION Algorithm:**

```
Summary of Results Comparison:
                 Variable                         Before_DG     After_DG
    _________________________________________    __________    __________

    'Min Voltage (p.u)'                          '0.96'        '0.99386'
    'Min Voltage at Bus Location'                '18'          '13'
    'Total Active Power Losses (kW)'             '47.6148'     '5.9532'
    'Total Active Power Losses (%)'              'NA'          '87.4971'
    'Total Reactive Power Losses (kVAR)'         '44.4792'     '4.71'
    'Total Reactive Power Losses (%)'            'NA'          '89.4107'
    'Power Factor'                               '0.70231'     '0.96926'

Additional Information related to DGs:
              Variable                                  Value
    __________________________________    ___________________________________________

    'DG Type'                             '3'
    'No of DGs'                           '3'
    'Location of DGs (Bus Number)'        '4   2   6'
    'Sizes of DGs in kW'                  '768.1084       134.6035        370.5708'
    'Sizes of DGs in kVAR'                '744.3397       817.2148        381.3133'
    'MOI'                                 '0.074188'
```

EXECUTIVE ENGINEER (E)
IESCO OPERATION DIVISION
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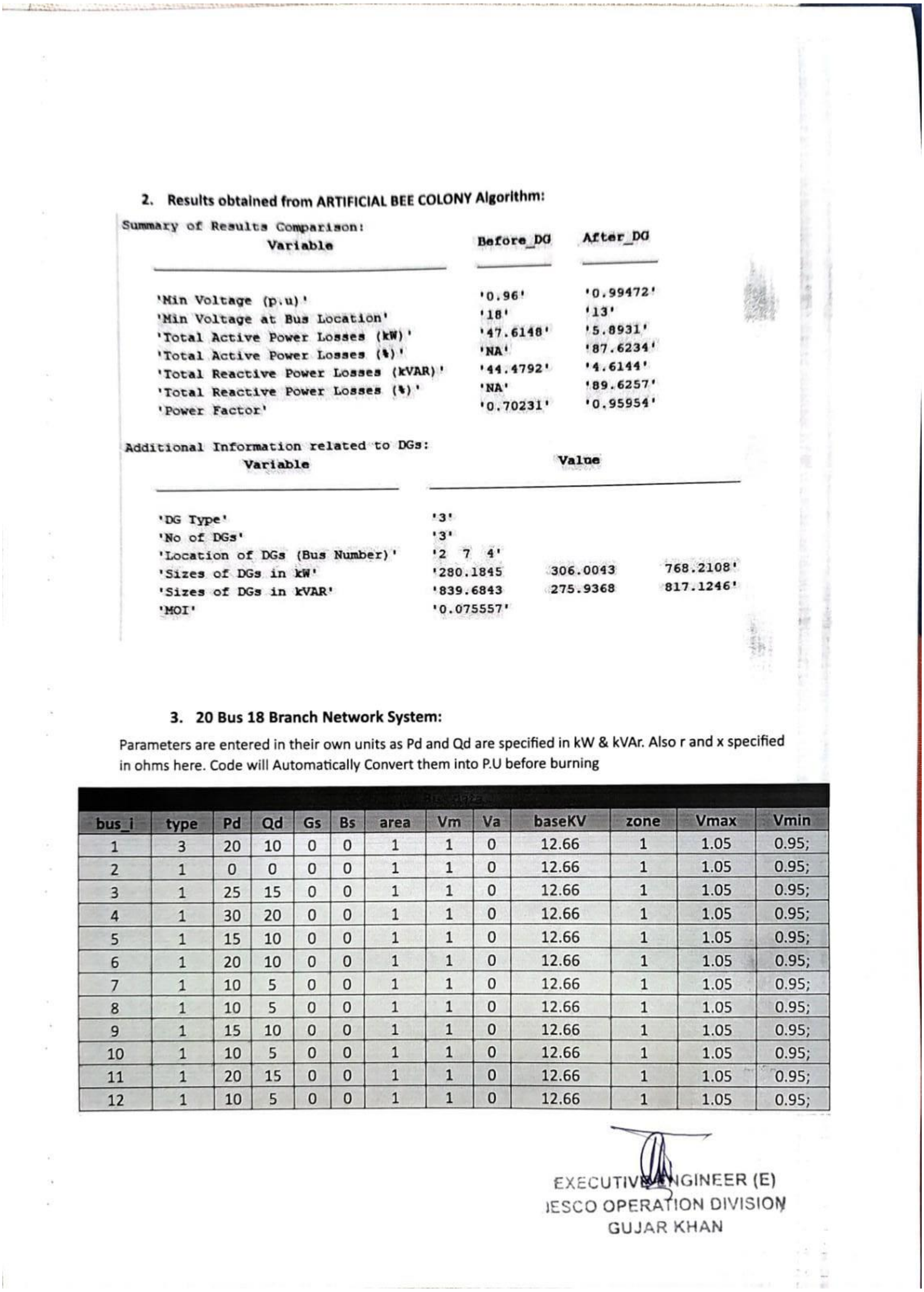

2. **Results obtained from ARTIFICIAL BEE COLONY Algorithm:**

```
Summary of Results Comparison:
                  Variable                          Before_DG     After_DG
      _________________________________________    _________     _________

      'Min Voltage (p.u)'                           '0.96'        '0.99472'
      'Min Voltage at Bus Location'                 '18'          '13'
      'Total Active Power Losses (kW)'              '47.6148'     '5.8931'
      'Total Active Power Losses (%)'               'NA'          '87.6234'
      'Total Reactive Power Losses (kVAR)'          '44.4792'     '4.6144'
      'Total Reactive Power Losses (%)'             'NA'          '89.6257'
      'Power Factor'                                '0.70231'     '0.95954'

Additional Information related to DGs:
              Variable                                    Value
      ________________________________    ________________________________________

      'DG Type'                           '3'
      'No of DGs'                         '3'
      'Location of DGs (Bus Number)'      '2   7   4'
      'Sizes of DGs in kW'                '280.1845      306.0043      768.2108'
      'Sizes of DGs in kVAR'              '839.6843      275.9368      817.1246'
      'MOI'                               '0.075557'
```

3. 20 Bus 18 Branch Network System:

Parameters are entered in their own units as Pd and Qd are specified in kW & kVAr. Also r and x specified in ohms here. Code will Automatically Convert them into P.U before burning

bus_i	type	Pd	Qd	Gs	Bs	area	Vm	Va	baseKV	zone	Vmax	Vmin
1	3	20	10	0	0	1	1	0	12.66	1	1.05	0.95;
2	1	0	0	0	0	1	1	0	12.66	1	1.05	0.95;
3	1	25	15	0	0	1	1	0	12.66	1	1.05	0.95;
4	1	30	20	0	0	1	1	0	12.66	1	1.05	0.95;
5	1	15	10	0	0	1	1	0	12.66	1	1.05	0.95;
6	1	20	10	0	0	1	1	0	12.66	1	1.05	0.95;
7	1	10	5	0	0	1	1	0	12.66	1	1.05	0.95;
8	1	10	5	0	0	1	1	0	12.66	1	1.05	0.95;
9	1	15	10	0	0	1	1	0	12.66	1	1.05	0.95;
10	1	10	5	0	0	1	1	0	12.66	1	1.05	0.95;
11	1	20	15	0	0	1	1	0	12.66	1	1.05	0.95;
12	1	10	5	0	0	1	1	0	12.66	1	1.05	0.95;

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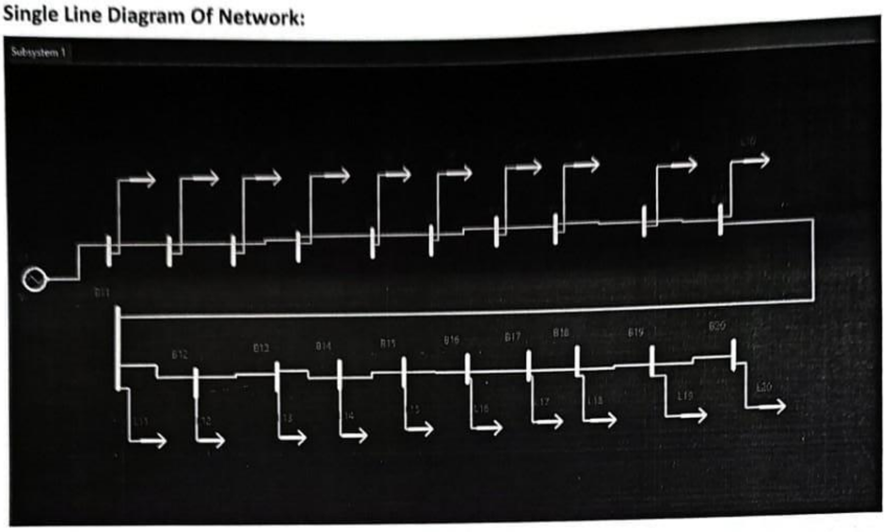
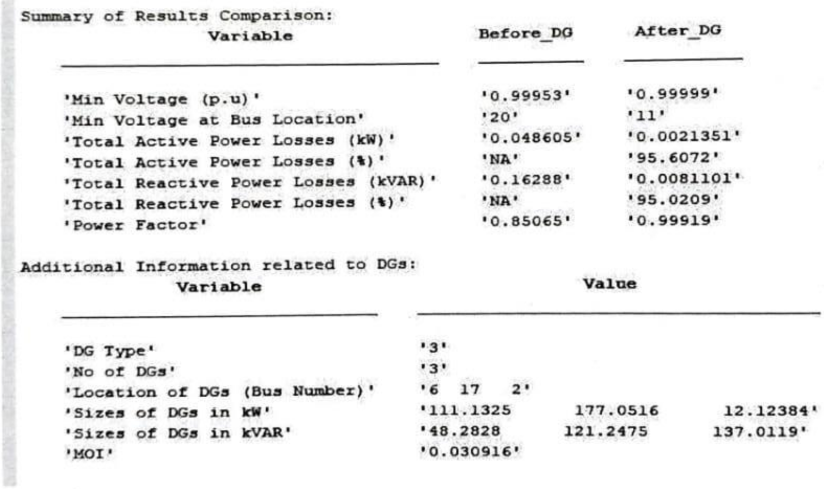
Single Line Diagram Of Network:



Results Summary Comparison Before & After D.G Placement:

1. **Results obtained from SEA HORSE OPTIMIZATION Algorithm:**



```
Summary of Results Comparison:
                   Variable                          Before_DG       After_DG
     ____________________________________________    __________    ____________

     'Min Voltage (p.u)'                             '0.99953'     '0.99999'
     'Min Voltage at Bus Location'                   '20'          '11'
     'Total Active Power Losses (kW)'                '0.048605'    '0.0021351'
     'Total Active Power Losses (%)'                 'NA'          '95.6072'
     'Total Reactive Power Losses (kVAR)'            '0.16288'     '0.0081101'
     'Total Reactive Power Losses (%)'               'NA'          '95.0209'
     'Power Factor'                                  '0.85065'     '0.99919'

Additional Information related to DGs:
                Variable                                    Value
     _____________________________________    _______________________________________________

     'DG Type'                                '3'
     'No of DGs'                              '3'
     'Location of DGs (Bus Number)'           '6   17   2'
     'Sizes of DGs in kW'                     '111.1325      177.0516       12.12384'
     'Sizes of DGs in kVAR'                   '48.2828      121.2475      137.0119'
     'MOI'                                    '0.030916'
```

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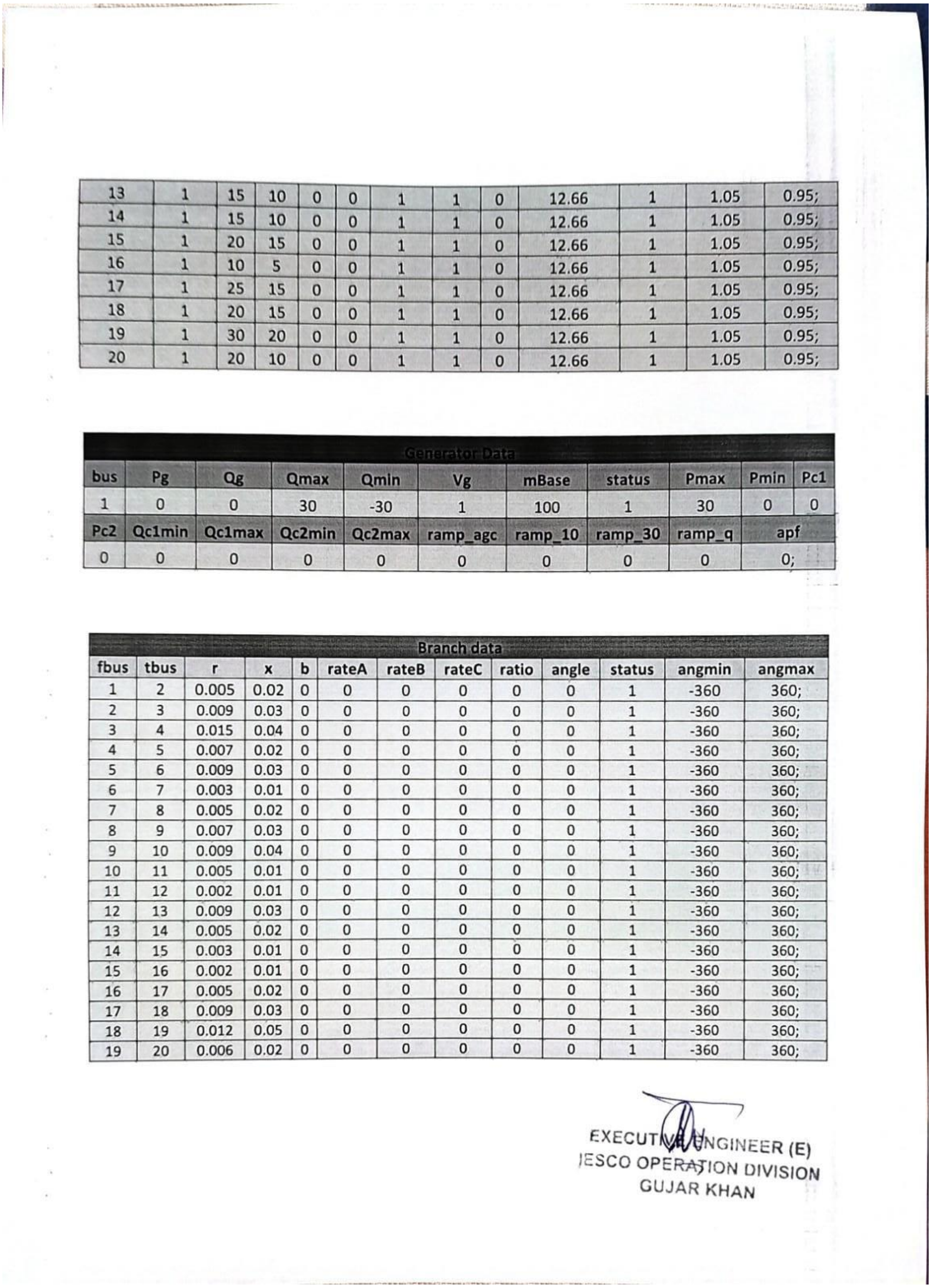

13	1	15	10	0	0	1	1	0	12.66	1	1.05	0.95;
14	1	15	10	0	0	1	1	0	12.66	1	1.05	0.95;
15	1	20	15	0	0	1	1	0	12.66	1	1.05	0.95;
16	1	10	5	0	0	1	1	0	12.66	1	1.05	0.95;
17	1	25	15	0	0	1	1	0	12.66	1	1.05	0.95;
18	1	20	15	0	0	1	1	0	12.66	1	1.05	0.95;
19	1	30	20	0	0	1	1	0	12.66	1	1.05	0.95;
20	1	20	10	0	0	1	1	0	12.66	1	1.05	0.95;

Generator Data

bus	Pg	Qg	Qmax	Qmin	Vg	mBase	status	Pmax	Pmin	Pc1
1	0	0	30	-30	1	100	1	30	0	0
Pc2	**Qc1min**	**Qc1max**	**Qc2min**	**Qc2max**	**ramp_agc**	**ramp_10**	**ramp_30**	**ramp_q**	**apf**	
0	0	0	0	0	0	0	0	0	0;	

Branch data

fbus	tbus	r	x	b	rateA	rateB	rateC	ratio	angle	status	angmin	angmax
1	2	0.005	0.02	0	0	0	0	0	0	1	-360	360;
2	3	0.009	0.03	0	0	0	0	0	0	1	-360	360;
3	4	0.015	0.04	0	0	0	0	0	0	1	-360	360;
4	5	0.007	0.02	0	0	0	0	0	0	1	-360	360;
5	6	0.009	0.03	0	0	0	0	0	0	1	-360	360;
6	7	0.003	0.01	0	0	0	0	0	0	1	-360	360;
7	8	0.005	0.02	0	0	0	0	0	0	1	-360	360;
8	9	0.007	0.03	0	0	0	0	0	0	1	-360	360;
9	10	0.009	0.04	0	0	0	0	0	0	1	-360	360;
10	11	0.005	0.01	0	0	0	0	0	0	1	-360	360;
11	12	0.002	0.01	0	0	0	0	0	0	1	-360	360;
12	13	0.009	0.03	0	0	0	0	0	0	1	-360	360;
13	14	0.005	0.02	0	0	0	0	0	0	1	-360	360;
14	15	0.003	0.01	0	0	0	0	0	0	1	-360	360;
15	16	0.002	0.01	0	0	0	0	0	0	1	-360	360;
16	17	0.005	0.02	0	0	0	0	0	0	1	-360	360;
17	18	0.009	0.03	0	0	0	0	0	0	1	-360	360;
18	19	0.012	0.05	0	0	0	0	0	0	1	-360	360;
19	20	0.006	0.02	0	0	0	0	0	0	1	-360	360;

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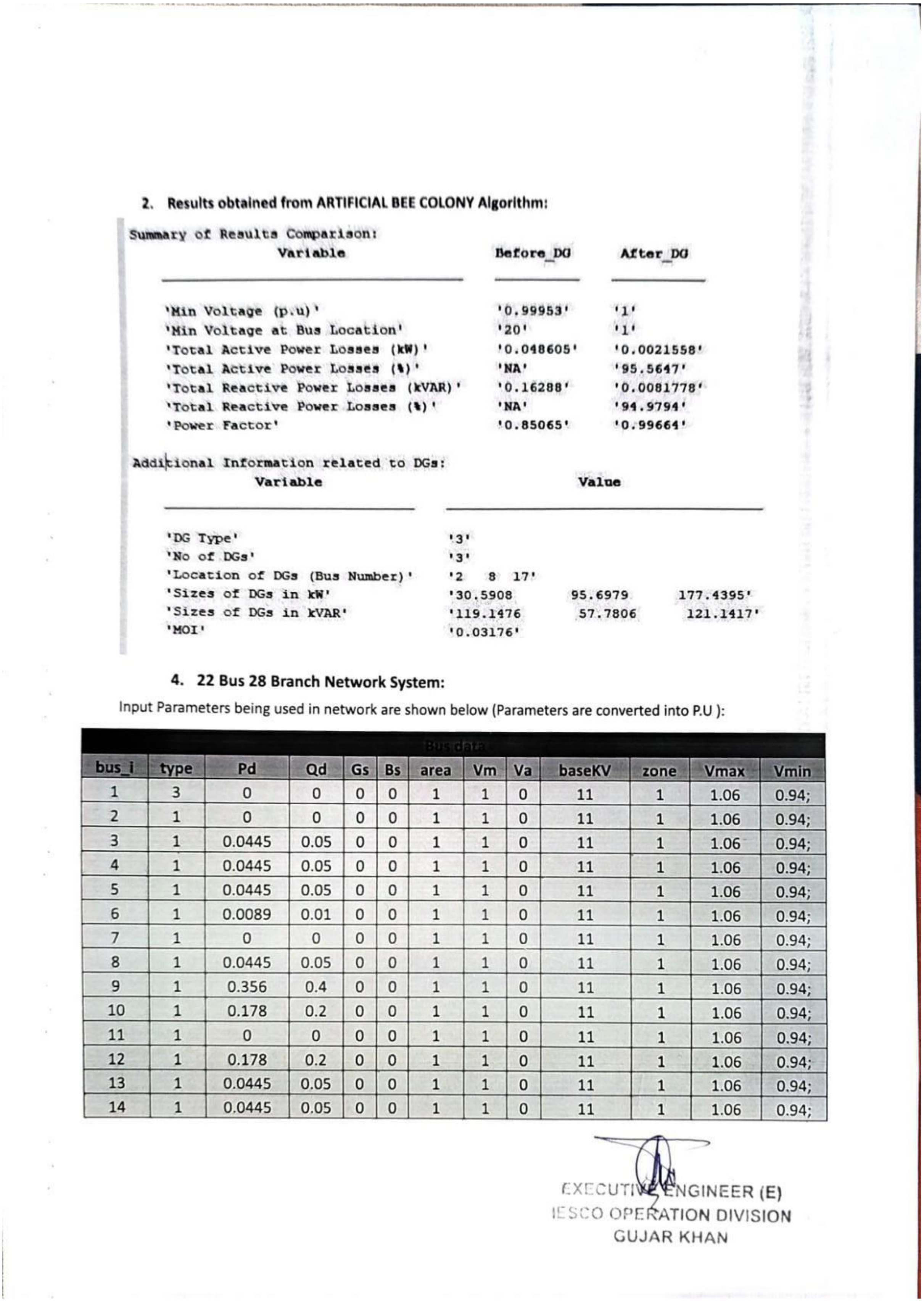

2. Results obtained from ARTIFICIAL BEE COLONY Algorithm:

```
Summary of Results Comparison:
                 Variable                         Before_DG       After_DG
         ________________________________      _________      _________

         'Min Voltage (p.u)'                     '0.99953'       '1'
         'Min Voltage at Bus Location'           '20'            '1'
         'Total Active Power Losses (kW)'        '0.048605'      '0.0021558'
         'Total Active Power Losses (%)'         'NA'            '95.5647'
         'Total Reactive Power Losses (kVAR)'    '0.16288'       '0.0081778'
         'Total Reactive Power Losses (%)'       'NA'            '94.9794'
         'Power Factor'                          '0.85065'       '0.99664'

Additional Information related to DGs:
              Variable                                 Value
         ___________________________     __________________________________

         'DG Type'                        '3'
         'No of DGs'                      '3'
         'Location of DGs (Bus Number)'   '2    8   17'
         'Sizes of DGs in kW'             '30.5908        95.6979        177.4395'
         'Sizes of DGs in kVAR'           '119.1476        57.7806        121.1417'
         'MOI'                            '0.03176'
```

4. 22 Bus 28 Branch Network System:

Input Parameters being used in network are shown below (Parameters are converted into P.U):

Bus data

bus_i	type	Pd	Qd	Gs	Bs	area	Vm	Va	baseKV	zone	Vmax	Vmin
1	3	0	0	0	0	1	1	0	11	1	1.06	0.94;
2	1	0	0	0	0	1	1	0	11	1	1.06	0.94;
3	1	0.0445	0.05	0	0	1	1	0	11	1	1.06	0.94;
4	1	0.0445	0.05	0	0	1	1	0	11	1	1.06	0.94;
5	1	0.0445	0.05	0	0	1	1	0	11	1	1.06	0.94;
6	1	0.0089	0.01	0	0	1	1	0	11	1	1.06	0.94;
7	1	0	0	0	0	1	1	0	11	1	1.06	0.94;
8	1	0.0445	0.05	0	0	1	1	0	11	1	1.06	0.94;
9	1	0.356	0.4	0	0	1	1	0	11	1	1.06	0.94;
10	1	0.178	0.2	0	0	1	1	0	11	1	1.06	0.94;
11	1	0	0	0	0	1	1	0	11	1	1.06	0.94;
12	1	0.178	0.2	0	0	1	1	0	11	1	1.06	0.94;
13	1	0.0445	0.05	0	0	1	1	0	11	1	1.06	0.94;
14	1	0.0445	0.05	0	0	1	1	0	11	1	1.06	0.94;

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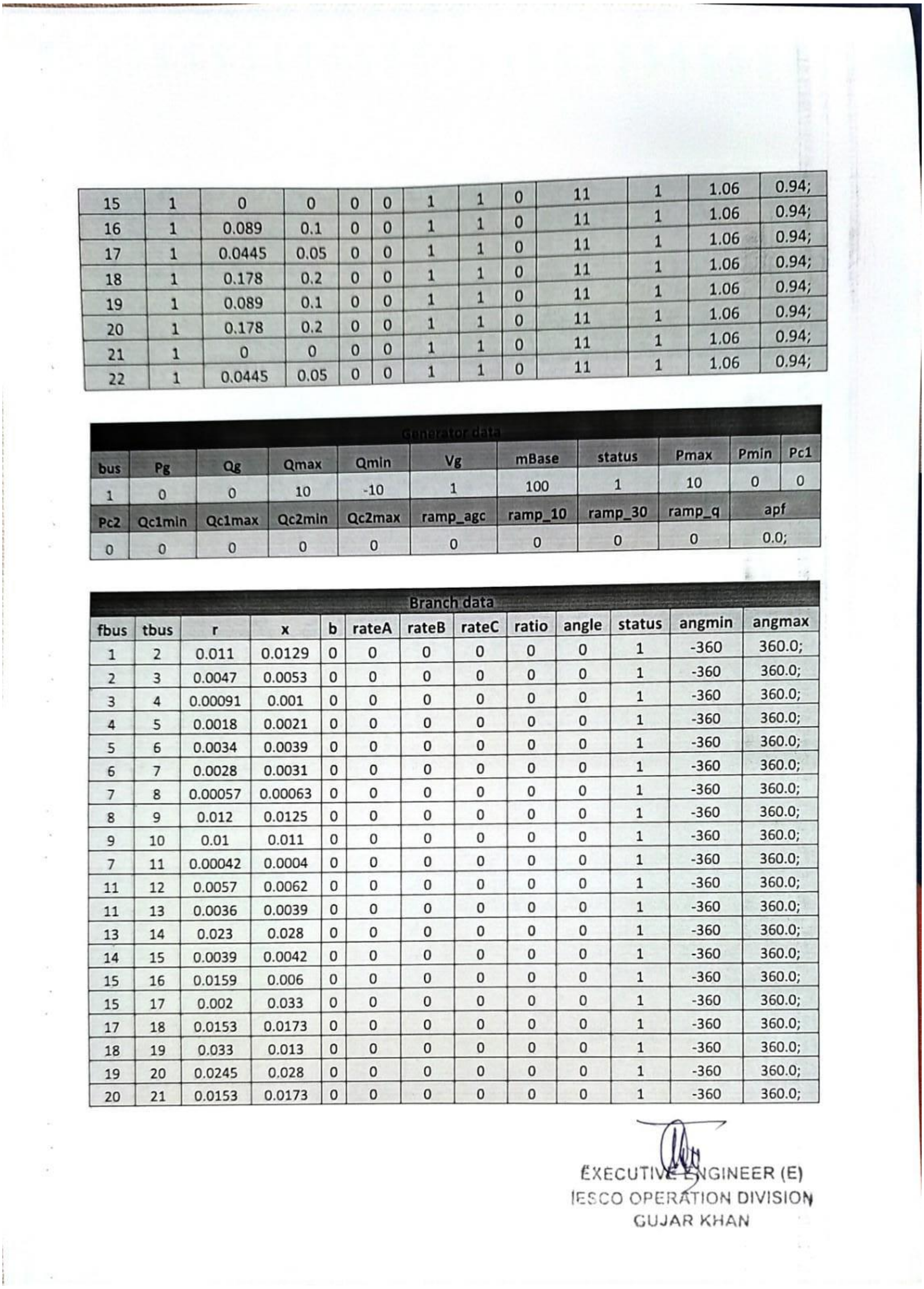

15	1	0	0	0	0	1	1	0	11	1	1.06	0.94;
16	1	0.089	0.1	0	0	1	1	0	11	1	1.06	0.94;
17	1	0.0445	0.05	0	0	1	1	0	11	1	1.06	0.94;
18	1	0.178	0.2	0	0	1	1	0	11	1	1.06	0.94;
19	1	0.089	0.1	0	0	1	1	0	11	1	1.06	0.94;
20	1	0.178	0.2	0	0	1	1	0	11	1	1.06	0.94;
21	1	0	0	0	0	1	1	0	11	1	1.06	0.94;
22	1	0.0445	0.05	0	0	1	1	0	11	1	1.06	0.94;

Generator data

bus	Pg	Qg	Qmax	Qmin	Vg	mBase	status	Pmax	Pmin	Pc1
1	0	0	10	-10	1	100	1	10	0	0
Pc2	**Qc1min**	**Qc1max**	**Qc2min**	**Qc2max**	**ramp_agc**	**ramp_10**	**ramp_30**	**ramp_q**	**apf**	
0	0	0	0	0	0	0	0	0	0.0;	

Branch data

fbus	tbus	r	x	b	rateA	rateB	rateC	ratio	angle	status	angmin	angmax
1	2	0.011	0.0129	0	0	0	0	0	0	1	-360	360.0;
2	3	0.0047	0.0053	0	0	0	0	0	0	1	-360	360.0;
3	4	0.00091	0.001	0	0	0	0	0	0	1	-360	360.0;
4	5	0.0018	0.0021	0	0	0	0	0	0	1	-360	360.0;
5	6	0.0034	0.0039	0	0	0	0	0	0	1	-360	360.0;
6	7	0.0028	0.0031	0	0	0	0	0	0	1	-360	360.0;
7	8	0.00057	0.00063	0	0	0	0	0	0	1	-360	360.0;
8	9	0.012	0.0125	0	0	0	0	0	0	1	-360	360.0;
9	10	0.01	0.011	0	0	0	0	0	0	1	-360	360.0;
7	11	0.00042	0.0004	0	0	0	0	0	0	1	-360	360.0;
11	12	0.0057	0.0062	0	0	0	0	0	0	1	-360	360.0;
11	13	0.0036	0.0039	0	0	0	0	0	0	1	-360	360.0;
13	14	0.023	0.028	0	0	0	0	0	0	1	-360	360.0;
14	15	0.0039	0.0042	0	0	0	0	0	0	1	-360	360.0;
15	16	0.0159	0.006	0	0	0	0	0	0	1	-360	360.0;
15	17	0.002	0.033	0	0	0	0	0	0	1	-360	360.0;
17	18	0.0153	0.0173	0	0	0	0	0	0	1	-360	360.0;
18	19	0.033	0.013	0	0	0	0	0	0	1	-360	360.0;
19	20	0.0245	0.028	0	0	0	0	0	0	1	-360	360.0;
20	21	0.0153	0.0173	0	0	0	0	0	0	1	-360	360.0;

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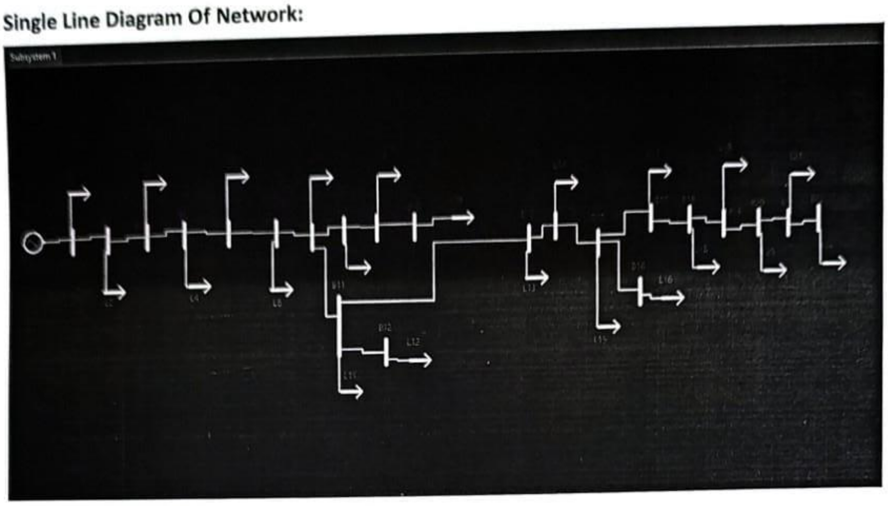
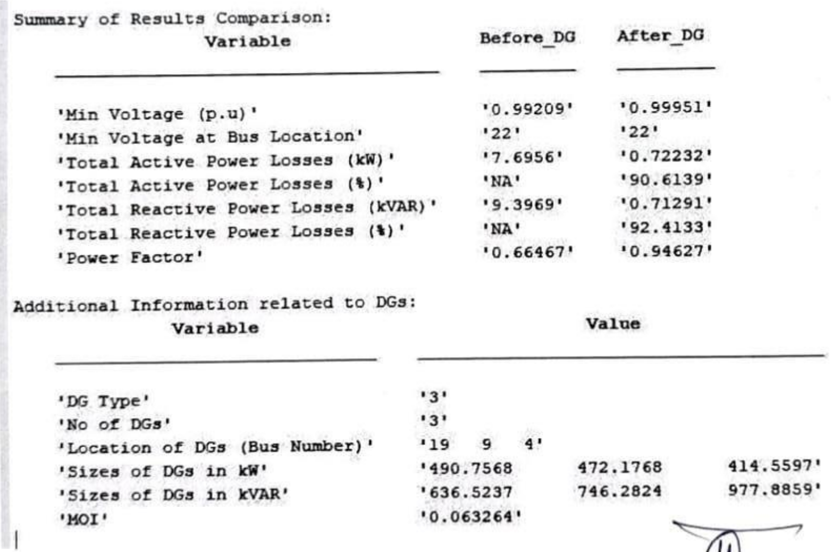
21	22	0.011	0.0129	0	0	0	0	0	0	1	-360	360.0;

Single Line Diagram Of Network:



Results Summary Comparison Before & After D.G Placement:

1. **Results obtained from SEA HORSE OPTIMIZATION Algorithm:**



```
Summary of Results Comparison:
                     Variable                          Before_DG    After_DG
          ______________________________________       _________    _________

          'Min Voltage (p.u)'                          '0.99209'    '0.99951'
          'Min Voltage at Bus Location'                '22'         '22'
          'Total Active Power Losses (kW)'             '7.6956'     '0.72232'
          'Total Active Power Losses (%)'              'NA'         '90.6139'
          'Total Reactive Power Losses (kVAR)'         '9.3969'     '0.71291'
          'Total Reactive Power Losses (%)'            'NA'         '92.4133'
          'Power Factor'                               '0.66467'    '0.94627'

Additional Information related to DGs:
                Variable                               Value
          ______________________________     ________________________________________

          'DG Type'                          '3'
          'No of DGs'                        '3'
          'Location of DGs (Bus Number)'     '19     9     4'
          'Sizes of DGs in kW'               '490.7568        472.1768        414.5597'
          'Sizes of DGs in kVAR'             '636.5237        746.2824        977.8859'
          'MOI'                              '0.063264'
```

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16	1	75	75	0	0	1	1	0	11	1	1.1	0.9;
17	1	45	45	0	0	1	1	0	11	1	1.1	0.9;
18	1	70	70	0	0	1	1	0	11	1	1.1	0.9;
19	1	60	60	0	0	1	1	0	11	1	1.1	0.9;
20	1	65	65	0	0	1	1	0	11	1	1.1	0.9;
21	1	90	90	0	0	1	1	0	11	1	1.1	0.9;
22	1	95	95	0	0	1	1	0	11	1	1.1	0.9;
23	1	120	120	0	0	1	1	0	11	1	1.1	0.9;
24	1	125	125	0	0	1	1	0	11	1	1.1	0.9;
25	1	145	145	0	0	1	1	0	11	1	1.1	0.9;
26	1	160	160	0	0	1	1	0	11	1	1.1	0.9;
27	1	65	65	0	0	1	1	0	11	1	1.1	0.9;

Generator Data

bus	Pg	Qg	Qmax	Qmin	Vg	mBase	status	Pmax	Pmin	Pc1
1	0	0	10	-10	1	100	1	10	0	0
Pc2	**Qc1min**	**Qc1max**	**Qc2min**	**Qc2max**	**ramp_agc**	**ramp_10**	**ramp_30**	**ramp_q**	**apf**	
0	0	0	0	0	0	0	0	0	0	

Branch data

fbus	tbus	r	x	b	rateA	rateB	rateC	ratio	angle	status	angmin	angmax
1	2	0.1	0.2	0	0	0	0	0	0	1	-360	360;
2	3	0.1	0.2	0	0	0	0	0	0	1	-360	360;
3	4	0.1	0.2	0	0	0	0	0	0	1	-360	360;
4	5	0.1	0.2	0	0	0	0	0	0	1	-360	360;
5	6	0.1	0.2	0	0	0	0	0	0	1	-360	360;
6	7	0.1	0.2	0	0	0	0	0	0	1	-360	360;
7	8	0.1	0.2	0	0	0	0	0	0	1	-360	360;
8	9	0.1	0.2	0	0	0	0	0	0	1	-360	360;
9	10	0.1	0.2	0	0	0	0	0	0	1	-360	360;
10	11	0.1	0.2	0	0	0	0	0	0	1	-360	360;
11	12	0.1	0.2	0	0	0	0	0	0	1	-360	360;
12	13	0.1	0.2	0	0	0	0	0	0	1	-360	360;
13	14	0.1	0.2	0	0	0	0	0	0	1	-360	360;
14	15	0.1	0.2	0	0	0	0	0	0	1	-360	360;
15	16	0.1	0.2	0	0	0	0	0	0	1	-360	360;
16	17	0.1	0.2	0	0	0	0	0	0	1	-360	360;
17	18	0.1	0.2	0	0	0	0	0	0	1	-360	360;
18	19	0.1	0.2	0	0	0	0	0	0	1	-360	360;
19	20	0.1	0.2	0	0	0	0	0	0	1	-360	360;
20	21	0.1	0.2	0	0	0	0	0	0	1	-360	360;

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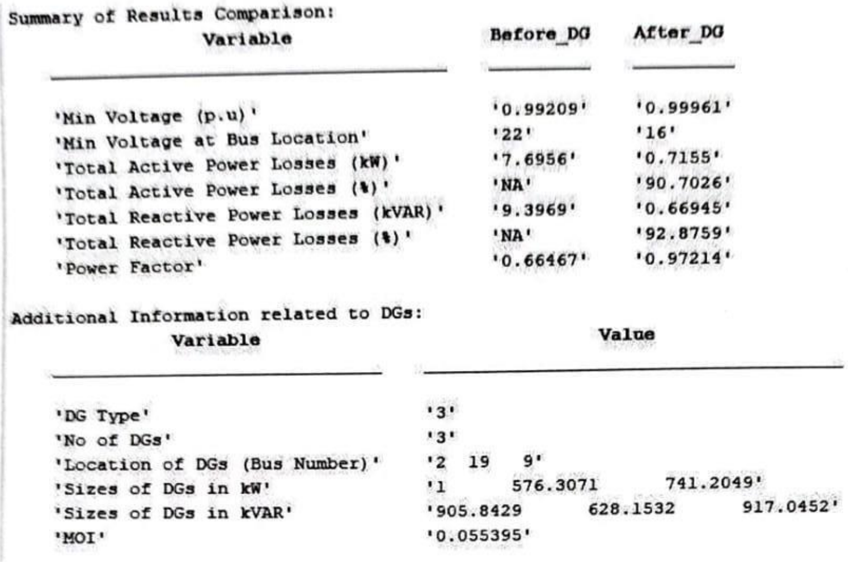
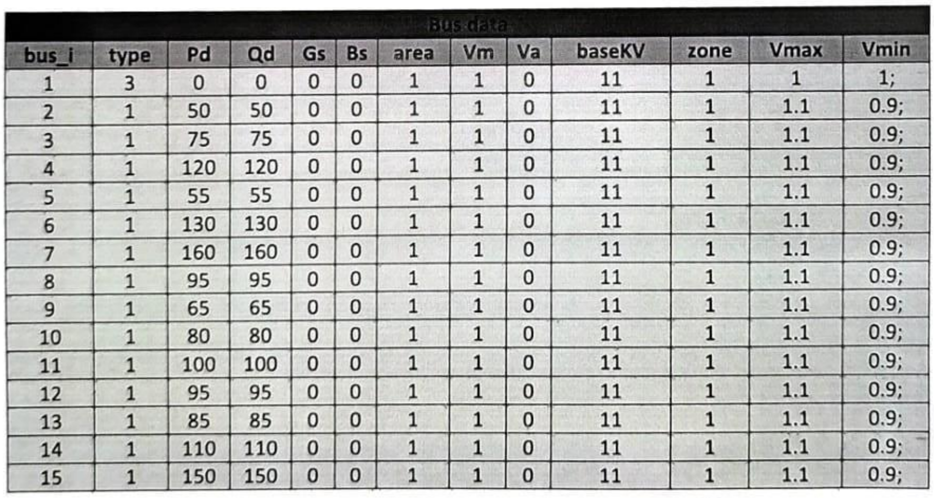
2. Results obtained from ARTIFICIAL BEE COLONY Algorithm:



```
Summary of Results Comparison:
                  Variable                         Before_DG     After_DG
    ______________________________________         _________     _________

    'Min Voltage (p.u)'                            '0.99209'     '0.99961'
    'Min Voltage at Bus Location'                  '22'          '16'
    'Total Active Power Losses (kW)'               '7.6956'      '0.7155'
    'Total Active Power Losses (%)'                'NA'          '90.7026'
    'Total Reactive Power Losses (kVAR)'           '9.3969'      '0.66945'
    'Total Reactive Power Losses (%)'              'NA'          '92.8759'
    'Power Factor'                                 '0.66467'     '0.97214'

Additional Information related to DGs:
              Variable                                  Value
    _________________________________    ____________________________________

    'DG Type'                            '3'
    'No of DGs'                          '3'
    'Location of DGs (Bus Number)'       '2   19   9'
    'Sizes of DGs in kW'                 '1        576.3071        741.2049'
    'Sizes of DGs in kVAR'               '905.8429        628.1532        917.0452'
    'MOI'                                '0.055395'
```

5. 27 Bus 27 Branch Network System:

Parameters are entered in their own units as Pd and Qd are specified in kW & kVAr. Also r and x specified in ohms here. Code will Automatically Convert them into P.U before burning



Bus data

bus_i	type	Pd	Qd	Gs	Bs	area	Vm	Va	baseKV	zone	Vmax	Vmin
1	3	0	0	0	0	1	1	0	11	1	1	1;
2	1	50	50	0	0	1	1	0	11	1	1.1	0.9;
3	1	75	75	0	0	1	1	0	11	1	1.1	0.9;
4	1	120	120	0	0	1	1	0	11	1	1.1	0.9;
5	1	55	55	0	0	1	1	0	11	1	1.1	0.9;
6	1	130	130	0	0	1	1	0	11	1	1.1	0.9;
7	1	160	160	0	0	1	1	0	11	1	1.1	0.9;
8	1	95	95	0	0	1	1	0	11	1	1.1	0.9;
9	1	65	65	0	0	1	1	0	11	1	1.1	0.9;
10	1	80	80	0	0	1	1	0	11	1	1.1	0.9;
11	1	100	100	0	0	1	1	0	11	1	1.1	0.9;
12	1	95	95	0	0	1	1	0	11	1	1.1	0.9;
13	1	85	85	0	0	1	1	0	11	1	1.1	0.9;
14	1	110	110	0	0	1	1	0	11	1	1.1	0.9;
15	1	150	150	0	0	1	1	0	11	1	1.1	0.9;

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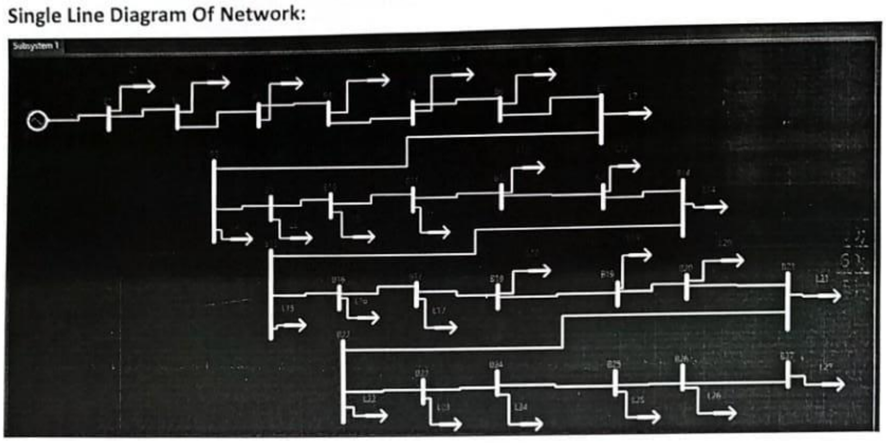
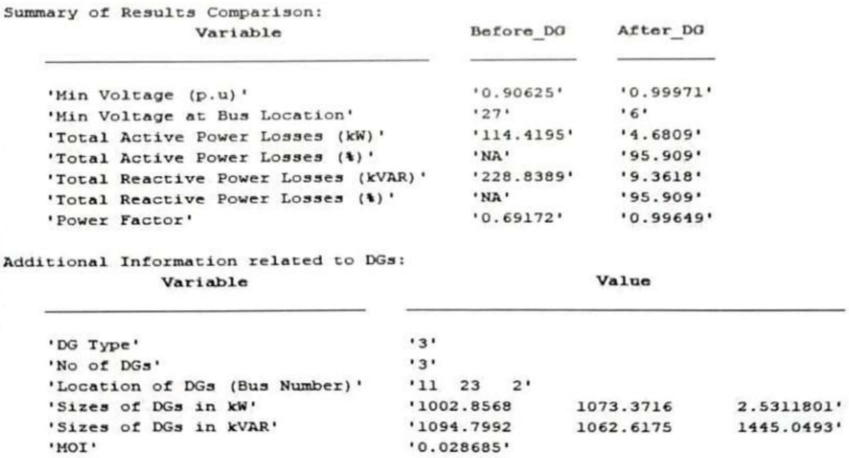
21	22	0.1	0.2	0	0	0	0	0	0	1	-360	360;
22	23	0.1	0.2	0	0	0	0	0	0	1	-360	360;
23	24	0.1	0.2	0	0	0	0	0	0	1	-360	360;
24	25	0.1	0.2	0	0	0	0	0	0	1	-360	360;
25	26	0.1	0.2	0	0	0	0	0	0	1	-360	360;
26	27	0.1	0.2	0	0	0	0	0	0	1	-360	360;

Single Line Diagram Of Network:



Results Summary Comparison Before & After D.G Placement:

1. **Results obtained from SEA HORSE OPTIMIZATION Algorithm:**



```
Summary of Results Comparison:
                  Variable                          Before_DG      After_DG
    ______________________________________        __________     __________

    'Min Voltage (p.u)'                            '0.90625'      '0.99971'
    'Min Voltage at Bus Location'                  '27'           '6'
    'Total Active Power Losses (kW)'               '114.4195'     '4.6809'
    'Total Active Power Losses (%)'                'NA'           '95.909'
    'Total Reactive Power Losses (kVAR)'           '228.8389'     '9.3618'
    'Total Reactive Power Losses (%)'              'NA'           '95.909'
    'Power Factor'                                 '0.69172'      '0.99649'

Additional Information related to DGs:
              Variable                                    Value
    _______________________________       _________________________________________

    'DG Type'                             '3'
    'No of DGs'                           '3'
    'Location of DGs (Bus Number)'        '11   23   2'
    'Sizes of DGs in kW'                  '1002.8568       1073.3716        2.5311801'
    'Sizes of DGs in kVAR'                '1094.7992       1062.6175        1445.0493'
    'MOI'                                 '0.028685'
```

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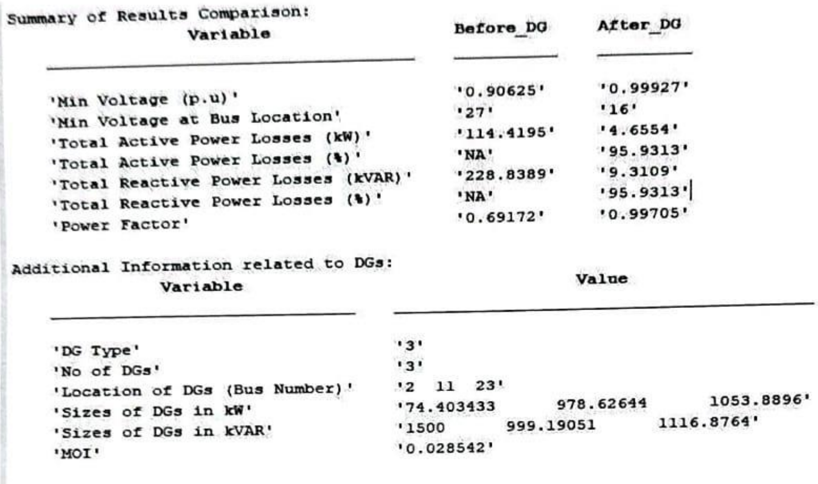
2. **Results obtained from ARTIFICIAL BEE COLONY Algorithm:**



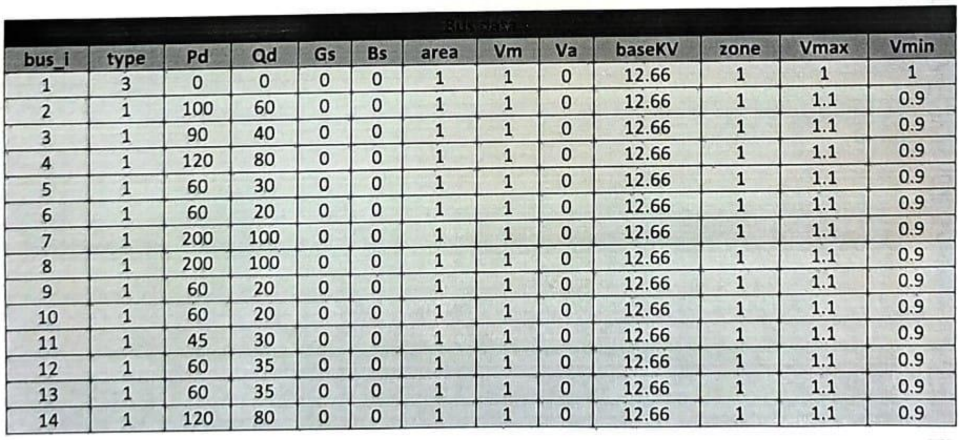
```
Summary of Results Comparison:
                  Variable                          Before_DG      After_DG
   ________________________________________        ___________    __________

   'Min Voltage (p.u)'                              '0.90625'      '0.99927'
   'Min Voltage at Bus Location'                    '27'           '16'
   'Total Active Power Losses (kW)'                 '114.4195'     '4.6554'
   'Total Active Power Losses (%)'                  'NA'           '95.9313'
   'Total Reactive Power Losses (kVAR)'             '228.8389'     '9.3109'
   'Total Reactive Power Losses (%)'                'NA'           '95.9313'
   'Power Factor'                                   '0.69172'      '0.99705'

Additional Information related to DGs:
                 Variable                                  Value
   ___________________________________    _____________________________________________

   'DG Type'                              '3'
   'No of DGs'                            '3'
   'Location of DGs (Bus Number)'         '2  11  23'
   'Sizes of DGs in kW'                   '74.403433        978.62644        1053.8896'
   'Sizes of DGs in kVAR'                 '1500      999.19051       1116.8764'
   'MOI'                                  '0.028542'
```

IEEE Standard Networks:

Following are the detailed parameters of IEEE Standard networks which are retrieved from Google for testing and **INVESTIGATION OF OPTIMAL POWER FACTOR IN DISTRIBUTION NETWORKS BASED ON DG PLACEMENT.**

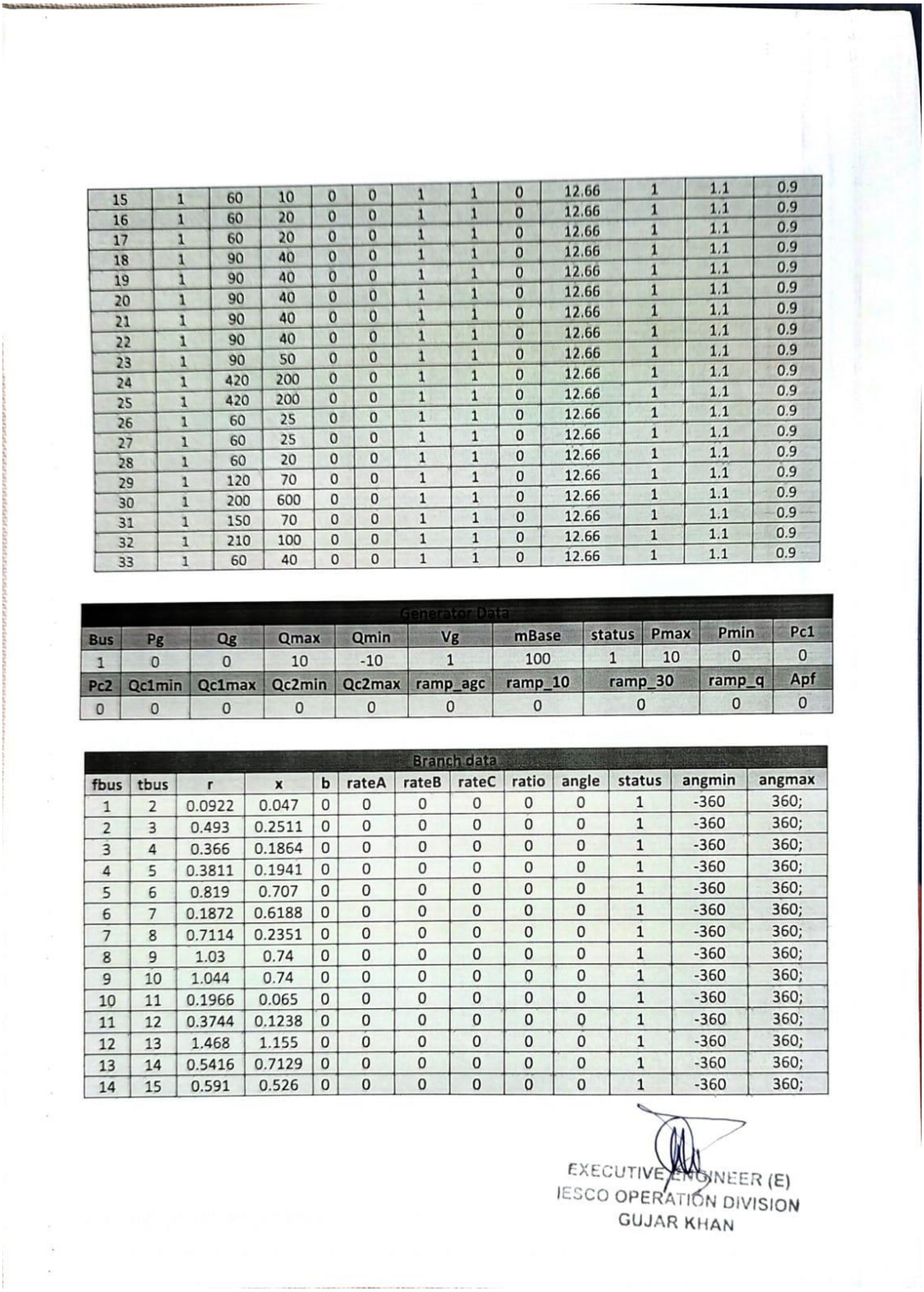
1. IEEE 33 Bus Network System:

Parameters are entered in their own units as Pd and Qd are specified in kW & kVAr. Also r and x specified in ohms here. Code will Automatically Convert them into P.U before burning



Bus Data

bus_i	type	Pd	Qd	Gs	Bs	area	Vm	Va	baseKV	zone	Vmax	Vmin
1	3	0	0	0	0	1	1	0	12.66	1	1	1
2	1	100	60	0	0	1	1	0	12.66	1	1.1	0.9
3	1	90	40	0	0	1	1	0	12.66	1	1.1	0.9
4	1	120	80	0	0	1	1	0	12.66	1	1.1	0.9
5	1	60	30	0	0	1	1	0	12.66	1	1.1	0.9
6	1	60	20	0	0	1	1	0	12.66	1	1.1	0.9
7	1	200	100	0	0	1	1	0	12.66	1	1.1	0.9
8	1	200	100	0	0	1	1	0	12.66	1	1.1	0.9
9	1	60	20	0	0	1	1	0	12.66	1	1.1	0.9
10	1	60	20	0	0	1	1	0	12.66	1	1.1	0.9
11	1	45	30	0	0	1	1	0	12.66	1	1.1	0.9
12	1	60	35	0	0	1	1	0	12.66	1	1.1	0.9
13	1	60	35	0	0	1	1	0	12.66	1	1.1	0.9
14	1	120	80	0	0	1	1	0	12.66	1	1.1	0.9



15	1	60	10	0	0	1	1	0	12.66	1	1.1	0.9
16	1	60	20	0	0	1	1	0	12.66	1	1.1	0.9
17	1	60	20	0	0	1	1	0	12.66	1	1.1	0.9
18	1	90	40	0	0	1	1	0	12.66	1	1.1	0.9
19	1	90	40	0	0	1	1	0	12.66	1	1.1	0.9
20	1	90	40	0	0	1	1	0	12.66	1	1.1	0.9
21	1	90	40	0	0	1	1	0	12.66	1	1.1	0.9
22	1	90	40	0	0	1	1	0	12.66	1	1.1	0.9
23	1	90	50	0	0	1	1	0	12.66	1	1.1	0.9
24	1	420	200	0	0	1	1	0	12.66	1	1.1	0.9
25	1	420	200	0	0	1	1	0	12.66	1	1.1	0.9
26	1	60	25	0	0	1	1	0	12.66	1	1.1	0.9
27	1	60	25	0	0	1	1	0	12.66	1	1.1	0.9
28	1	60	20	0	0	1	1	0	12.66	1	1.1	0.9
29	1	120	70	0	0	1	1	0	12.66	1	1.1	0.9
30	1	200	600	0	0	1	1	0	12.66	1	1.1	0.9
31	1	150	70	0	0	1	1	0	12.66	1	1.1	0.9
32	1	210	100	0	0	1	1	0	12.66	1	1.1	0.9
33	1	60	40	0	0	1	1	0	12.66	1	1.1	0.9

Generator Data

Bus	Pg	Qg	Qmax	Qmin	Vg	mBase	status	Pmax	Pmin	Pc1
1	0	0	10	-10	1	100	1	10	0	0
Pc2	**Qc1min**	**Qc1max**	**Qc2min**	**Qc2max**	**ramp_agc**	**ramp_10**	**ramp_30**		**ramp_q**	**Apf**
0	0	0	0	0	0	0	0		0	0

Branch data

fbus	tbus	r	x	b	rateA	rateB	rateC	ratio	angle	status	angmin	angmax
1	2	0.0922	0.047	0	0	0	0	0	0	1	-360	360;
2	3	0.493	0.2511	0	0	0	0	0	0	1	-360	360;
3	4	0.366	0.1864	0	0	0	0	0	0	1	-360	360;
4	5	0.3811	0.1941	0	0	0	0	0	0	1	-360	360;
5	6	0.819	0.707	0	0	0	0	0	0	1	-360	360;
6	7	0.1872	0.6188	0	0	0	0	0	0	1	-360	360;
7	8	0.7114	0.2351	0	0	0	0	0	0	1	-360	360;
8	9	1.03	0.74	0	0	0	0	0	0	1	-360	360;
9	10	1.044	0.74	0	0	0	0	0	0	1	-360	360;
10	11	0.1966	0.065	0	0	0	0	0	0	1	-360	360;
11	12	0.3744	0.1238	0	0	0	0	0	0	1	-360	360;
12	13	1.468	1.155	0	0	0	0	0	0	1	-360	360;
13	14	0.5416	0.7129	0	0	0	0	0	0	1	-360	360;
14	15	0.591	0.526	0	0	0	0	0	0	1	-360	360;

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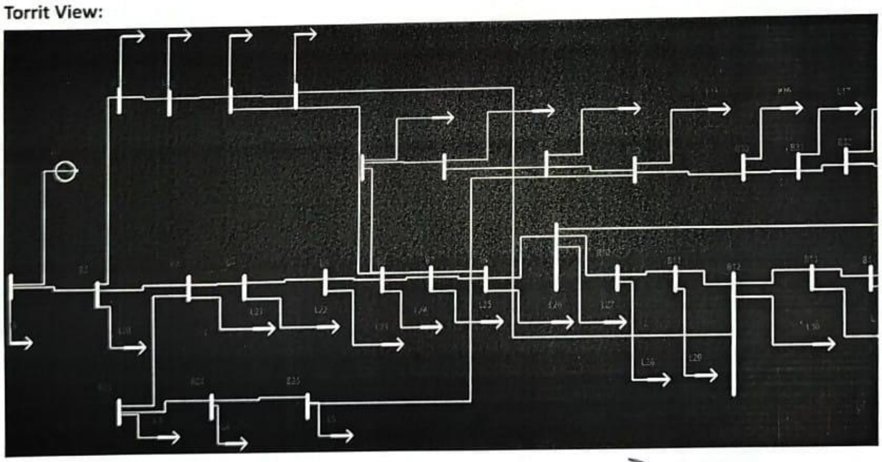
15	16	0.7463	0.545	0	0	0	0	0	0	1	-360	360;
16	17	1.289	1.721	0	0	0	0	0	0	1	-360	360;
17	18	0.732	0.574	0	0	0	0	0	0	1	-360	360;
2	19	0.164	0.1565	0	0	0	0	0	0	1	-360	360;
19	20	1.5042	1.3554	0	0	0	0	0	0	1	-360	360;
20	21	0.4095	0.4784	0	0	0	0	0	0	1	-360	360;
21	22	0.7089	0.9373	0	0	0	0	0	0	1	-360	360;
3	23	0.4512	0.3083	0	0	0	0	0	0	1	-360	360;
23	24	0.898	0.7091	0	0	0	0	0	0	1	-360	360;
24	25	0.896	0.7011	0	0	0	0	0	0	1	-360	360;
6	26	0.203	0.1034	0	0	0	0	0	0	1	-360	360;
26	27	0.2842	0.1447	0	0	0	0	0	0	1	-360	360;
27	28	1.059	0.9337	0	0	0	0	0	0	1	-360	360;
28	29	0.8042	0.7006	0	0	0	0	0	0	1	-360	360;
29	30	0.5075	0.2585	0	0	0	0	0	0	1	-360	360;
30	31	0.9744	0.963	0	0	0	0	0	0	1	-360	360;
31	32	0.3105	0.3619	0	0	0	0	0	0	1	-360	360;
32	33	0.341	0.5302	0	0	0	0	0	0	1	-360	360;
21	8	2	2	0	0	0	0	0	0	0	-360	360;
9	15	2	2	0	0	0	0	0	0	0	-360	360;
12	22	2	2	0	0	0	0	0	0	0	-360	360;
18	33	0.5	0.5	0	0	0	0	0	0	0	-360	360;
25	29	0.5	0.5	0	0	0	0	0	0	0	-360	360;

Single Line Diagram Of Network:

Torrit View:



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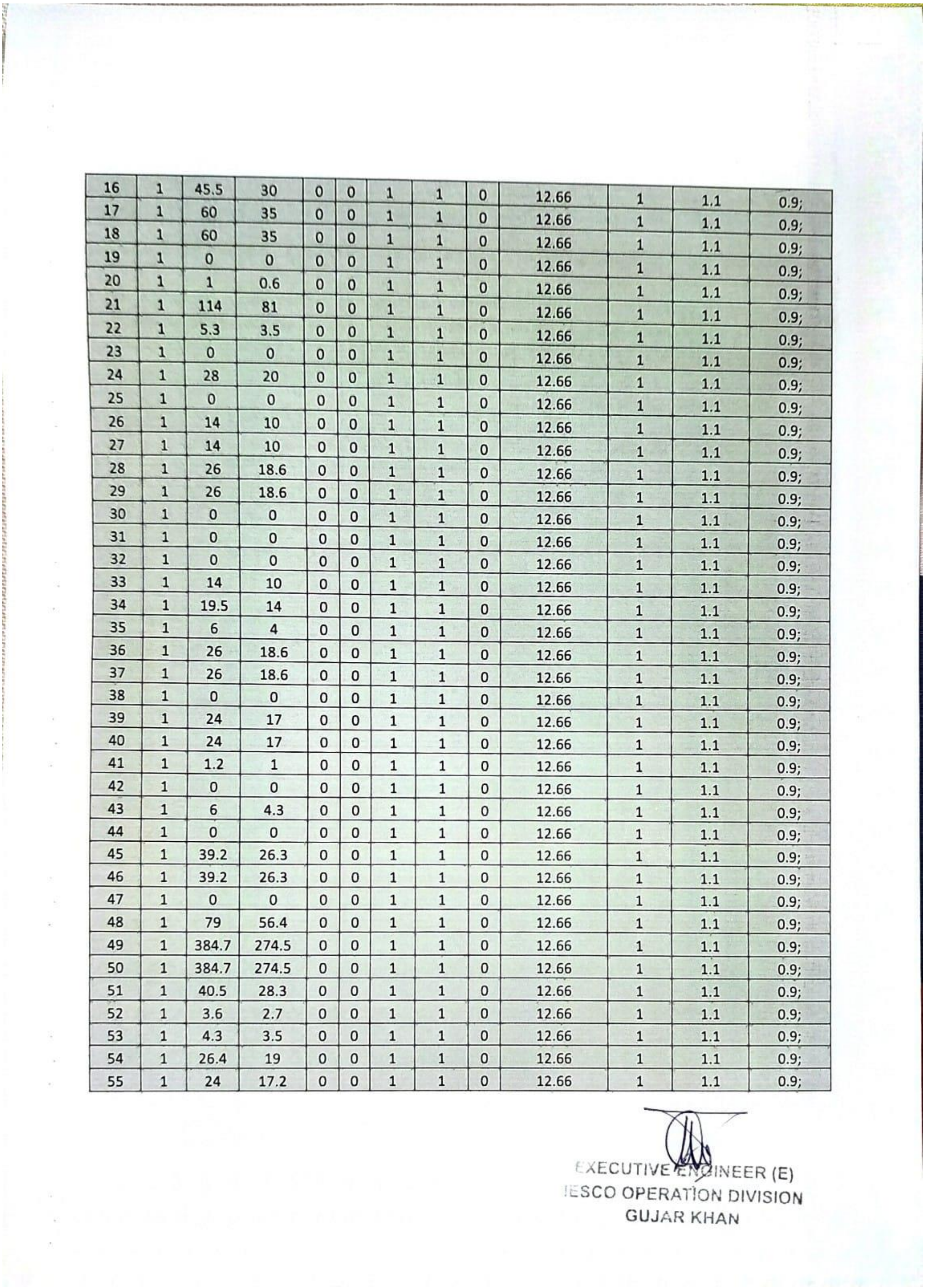

16	1	45.5	30	0	0	1	1	0	12.66	1	1.1	0.9;
17	1	60	35	0	0	1	1	0	12.66	1	1.1	0.9;
18	1	60	35	0	0	1	1	0	12.66	1	1.1	0.9;
19	1	0	0	0	0	1	1	0	12.66	1	1.1	0.9;
20	1	1	0.6	0	0	1	1	0	12.66	1	1.1	0.9;
21	1	114	81	0	0	1	1	0	12.66	1	1.1	0.9;
22	1	5.3	3.5	0	0	1	1	0	12.66	1	1.1	0.9;
23	1	0	0	0	0	1	1	0	12.66	1	1.1	0.9;
24	1	28	20	0	0	1	1	0	12.66	1	1.1	0.9;
25	1	0	0	0	0	1	1	0	12.66	1	1.1	0.9;
26	1	14	10	0	0	1	1	0	12.66	1	1.1	0.9;
27	1	14	10	0	0	1	1	0	12.66	1	1.1	0.9;
28	1	26	18.6	0	0	1	1	0	12.66	1	1.1	0.9;
29	1	26	18.6	0	0	1	1	0	12.66	1	1.1	0.9;
30	1	0	0	0	0	1	1	0	12.66	1	1.1	0.9;
31	1	0	0	0	0	1	1	0	12.66	1	1.1	0.9;
32	1	0	0	0	0	1	1	0	12.66	1	1.1	0.9;
33	1	14	10	0	0	1	1	0	12.66	1	1.1	0.9;
34	1	19.5	14	0	0	1	1	0	12.66	1	1.1	0.9;
35	1	6	4	0	0	1	1	0	12.66	1	1.1	0.9;
36	1	26	18.6	0	0	1	1	0	12.66	1	1.1	0.9;
37	1	26	18.6	0	0	1	1	0	12.66	1	1.1	0.9;
38	1	0	0	0	0	1	1	0	12.66	1	1.1	0.9;
39	1	24	17	0	0	1	1	0	12.66	1	1.1	0.9;
40	1	24	17	0	0	1	1	0	12.66	1	1.1	0.9;
41	1	1.2	1	0	0	1	1	0	12.66	1	1.1	0.9;
42	1	0	0	0	0	1	1	0	12.66	1	1.1	0.9;
43	1	6	4.3	0	0	1	1	0	12.66	1	1.1	0.9;
44	1	0	0	0	0	1	1	0	12.66	1	1.1	0.9;
45	1	39.2	26.3	0	0	1	1	0	12.66	1	1.1	0.9;
46	1	39.2	26.3	0	0	1	1	0	12.66	1	1.1	0.9;
47	1	0	0	0	0	1	1	0	12.66	1	1.1	0.9;
48	1	79	56.4	0	0	1	1	0	12.66	1	1.1	0.9;
49	1	384.7	274.5	0	0	1	1	0	12.66	1	1.1	0.9;
50	1	384.7	274.5	0	0	1	1	0	12.66	1	1.1	0.9;
51	1	40.5	28.3	0	0	1	1	0	12.66	1	1.1	0.9;
52	1	3.6	2.7	0	0	1	1	0	12.66	1	1.1	0.9;
53	1	4.3	3.5	0	0	1	1	0	12.66	1	1.1	0.9;
54	1	26.4	19	0	0	1	1	0	12.66	1	1.1	0.9;
55	1	24	17.2	0	0	1	1	0	12.66	1	1.1	0.9;

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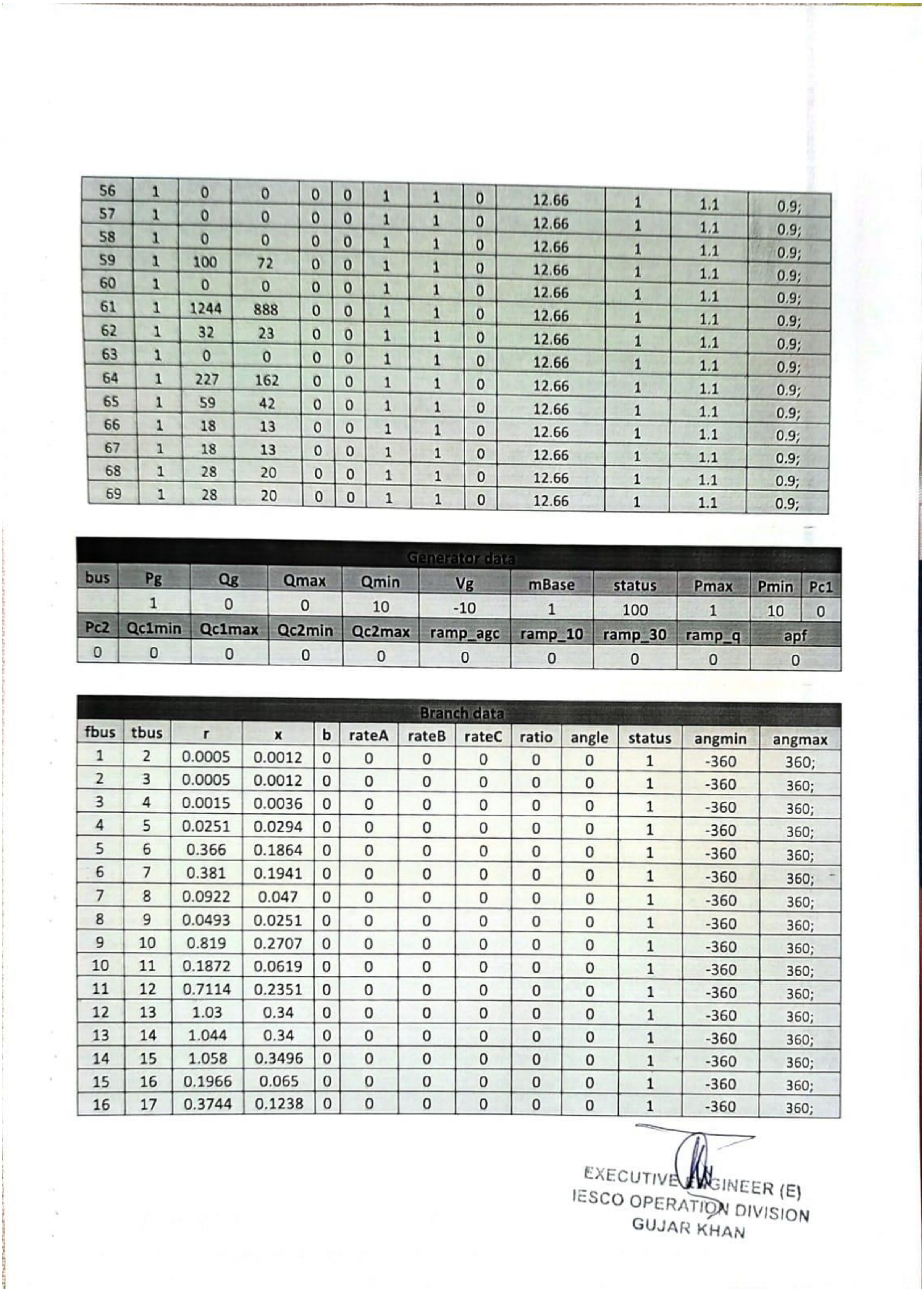

56	1	0	0	0	0	1	1	0	12.66	1	1.1	0.9;
57	1	0	0	0	0	1	1	0	12.66	1	1.1	0.9;
58	1	0	0	0	0	1	1	0	12.66	1	1.1	0.9;
59	1	100	72	0	0	1	1	0	12.66	1	1.1	0.9;
60	1	0	0	0	0	1	1	0	12.66	1	1.1	0.9;
61	1	1244	888	0	0	1	1	0	12.66	1	1.1	0.9;
62	1	32	23	0	0	1	1	0	12.66	1	1.1	0.9;
63	1	0	0	0	0	1	1	0	12.66	1	1.1	0.9;
64	1	227	162	0	0	1	1	0	12.66	1	1.1	0.9;
65	1	59	42	0	0	1	1	0	12.66	1	1.1	0.9;
66	1	18	13	0	0	1	1	0	12.66	1	1.1	0.9;
67	1	18	13	0	0	1	1	0	12.66	1	1.1	0.9;
68	1	28	20	0	0	1	1	0	12.66	1	1.1	0.9;
69	1	28	20	0	0	1	1	0	12.66	1	1.1	0.9;

Generator data

bus	Pg	Qg	Qmax	Qmin	Vg	mBase	status	Pmax	Pmin	Pc1
	1	0	0	10	-10	1	100	1	10	0
Pc2	**Qc1min**	**Qc1max**	**Qc2min**	**Qc2max**	**ramp_agc**	**ramp_10**	**ramp_30**	**ramp_q**	**apf**	
0	0	0	0	0	0	0	0	0	0	

Branch data

fbus	tbus	r	x	b	rateA	rateB	rateC	ratio	angle	status	angmin	angmax
1	2	0.0005	0.0012	0	0	0	0	0	0	1	-360	360;
2	3	0.0005	0.0012	0	0	0	0	0	0	1	-360	360;
3	4	0.0015	0.0036	0	0	0	0	0	0	1	-360	360;
4	5	0.0251	0.0294	0	0	0	0	0	0	1	-360	360;
5	6	0.366	0.1864	0	0	0	0	0	0	1	-360	360;
6	7	0.381	0.1941	0	0	0	0	0	0	1	-360	360;
7	8	0.0922	0.047	0	0	0	0	0	0	1	-360	360;
8	9	0.0493	0.0251	0	0	0	0	0	0	1	-360	360;
9	10	0.819	0.2707	0	0	0	0	0	0	1	-360	360;
10	11	0.1872	0.0619	0	0	0	0	0	0	1	-360	360;
11	12	0.7114	0.2351	0	0	0	0	0	0	1	-360	360;
12	13	1.03	0.34	0	0	0	0	0	0	1	-360	360;
13	14	1.044	0.34	0	0	0	0	0	0	1	-360	360;
14	15	1.058	0.3496	0	0	0	0	0	0	1	-360	360;
15	16	0.1966	0.065	0	0	0	0	0	0	1	-360	360;
16	17	0.3744	0.1238	0	0	0	0	0	0	1	-360	360;

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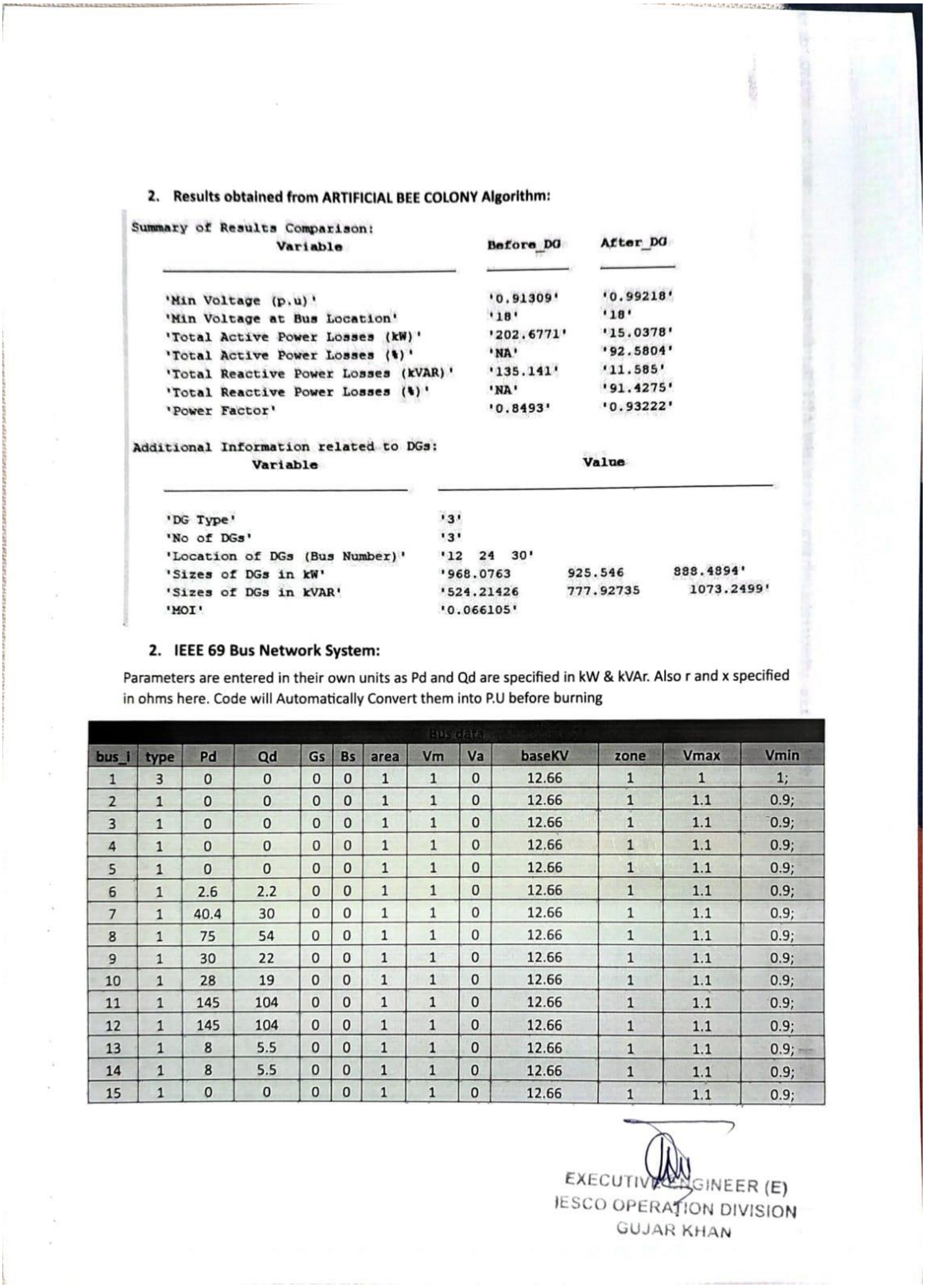

2. Results obtained from ARTIFICIAL BEE COLONY Algorithm:

```
Summary of Results Comparison:
                Variable                          Before_DG     After_DG

     ___________________________________        __________    _________

     'Min Voltage (p.u)'                          '0.91309'     '0.99218'
     'Min Voltage at Bus Location'                '18'          '18'
     'Total Active Power Losses (kW)'             '202.6771'    '15.0378'
     'Total Active Power Losses (%)'              'NA'          '92.5804'
     'Total Reactive Power Losses (kVAR)'         '135.141'     '11.585'
     'Total Reactive Power Losses (%)'            'NA'          '91.4275'
     'Power Factor'                               '0.8493'      '0.93222'

Additional Information related to DGs:
              Variable                                  Value

     ______________________________    _________________________________________

     'DG Type'                         '3'
     'No of DGs'                       '3'
     'Location of DGs (Bus Number)'    '12  24  30'
     'Sizes of DGs in kW'              '968.0763        925.546        888.4894'
     'Sizes of DGs in kVAR'            '524.21426       777.92735        1073.2499'
     'MOI'                             '0.066105'
```

2. IEEE 69 Bus Network System:

Parameters are entered in their own units as Pd and Qd are specified in kW & kVAr. Also r and x specified in ohms here. Code will Automatically Convert them into P.U before burning

Bus data												
bus_i	type	Pd	Qd	Gs	Bs	area	Vm	Va	baseKV	zone	Vmax	Vmin
1	3	0	0	0	0	1	1	0	12.66	1	1	1;
2	1	0	0	0	0	1	1	0	12.66	1	1.1	0.9;
3	1	0	0	0	0	1	1	0	12.66	1	1.1	0.9;
4	1	0	0	0	0	1	1	0	12.66	1	1.1	0.9;
5	1	0	0	0	0	1	1	0	12.66	1	1.1	0.9;
6	1	2.6	2.2	0	0	1	1	0	12.66	1	1.1	0.9;
7	1	40.4	30	0	0	1	1	0	12.66	1	1.1	0.9;
8	1	75	54	0	0	1	1	0	12.66	1	1.1	0.9;
9	1	30	22	0	0	1	1	0	12.66	1	1.1	0.9;
10	1	28	19	0	0	1	1	0	12.66	1	1.1	0.9;
11	1	145	104	0	0	1	1	0	12.66	1	1.1	0.9;
12	1	145	104	0	0	1	1	0	12.66	1	1.1	0.9;
13	1	8	5.5	0	0	1	1	0	12.66	1	1.1	0.9;
14	1	8	5.5	0	0	1	1	0	12.66	1	1.1	0.9;
15	1	0	0	0	0	1	1	0	12.66	1	1.1	0.9;

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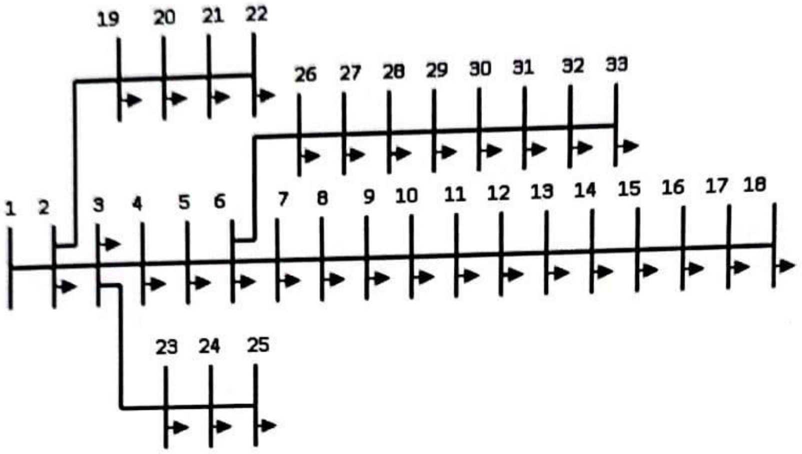
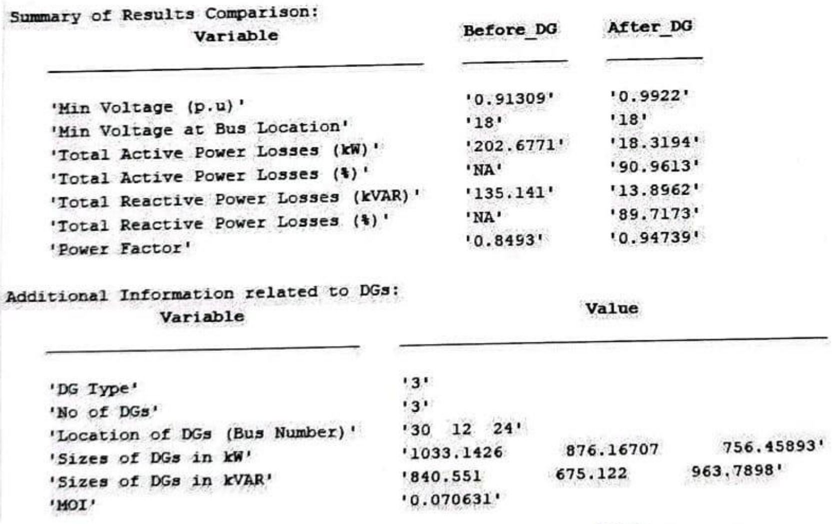
Standard View:



Results Summary Comparison Before & After D.G Placement:

1. **Results obtained from SEA HORSE OPTIMIZATION Algorithm:**



```
Summary of Results Comparison:
                    Variable                          Before_DG      After_DG
     _____________________________________________    __________     __________

     'Min Voltage (p.u)'                              '0.91309'      '0.9922'
     'Min Voltage at Bus Location'                    '18'           '18'
     'Total Active Power Losses (kW)'                 '202.6771'     '18.3194'
     'Total Active Power Losses (%)'                  'NA'           '90.9613'
     'Total Reactive Power Losses (kVAR)'             '135.141'      '13.8962'
     'Total Reactive Power Losses (%)'                'NA'           '89.7173'
     'Power Factor'                                   '0.8493'       '0.94739'

Additional Information related to DGs:
                  Variable                                     Value
     _________________________________    ______________________________________________

     'DG Type'                            '3'
     'No of DGs'                          '3'
     'Location of DGs (Bus Number)'       '30   12   24'
     'Sizes of DGs in kW'                 '1033.1426       876.16707        756.45893'
     'Sizes of DGs in kVAR'               '840.551        675.122        963.7898'
     'MOI'                                '0.070631'
```

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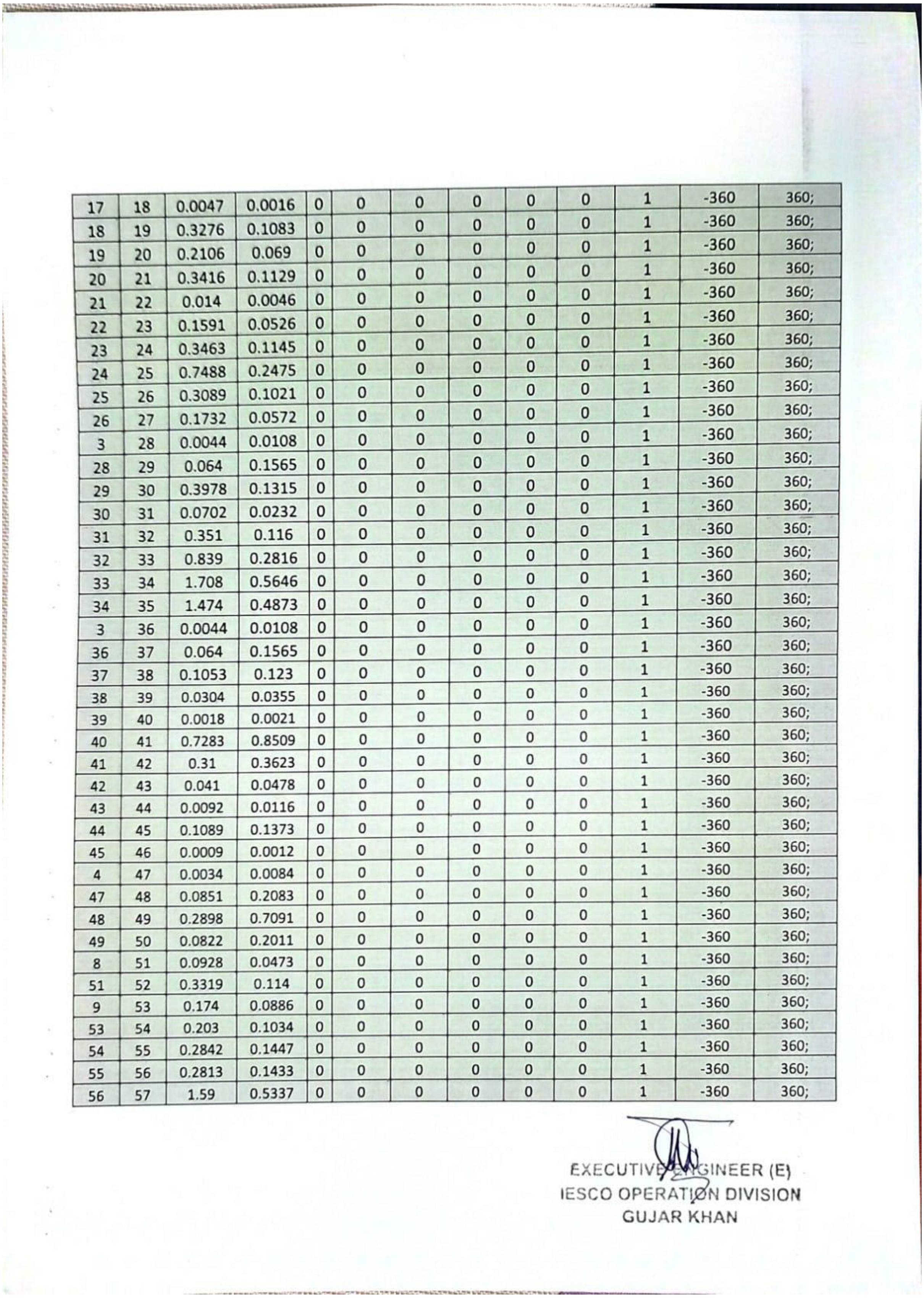

17	18	0.0047	0.0016	0	0	0	0	0	0	1	-360	360;
18	19	0.3276	0.1083	0	0	0	0	0	0	1	-360	360;
19	20	0.2106	0.069	0	0	0	0	0	0	1	-360	360;
20	21	0.3416	0.1129	0	0	0	0	0	0	1	-360	360;
21	22	0.014	0.0046	0	0	0	0	0	0	1	-360	360;
22	23	0.1591	0.0526	0	0	0	0	0	0	1	-360	360;
23	24	0.3463	0.1145	0	0	0	0	0	0	1	-360	360;
24	25	0.7488	0.2475	0	0	0	0	0	0	1	-360	360;
25	26	0.3089	0.1021	0	0	0	0	0	0	1	-360	360;
26	27	0.1732	0.0572	0	0	0	0	0	0	1	-360	360;
3	28	0.0044	0.0108	0	0	0	0	0	0	1	-360	360;
28	29	0.064	0.1565	0	0	0	0	0	0	1	-360	360;
29	30	0.3978	0.1315	0	0	0	0	0	0	1	-360	360;
30	31	0.0702	0.0232	0	0	0	0	0	0	1	-360	360;
31	32	0.351	0.116	0	0	0	0	0	0	1	-360	360;
32	33	0.839	0.2816	0	0	0	0	0	0	1	-360	360;
33	34	1.708	0.5646	0	0	0	0	0	0	1	-360	360;
34	35	1.474	0.4873	0	0	0	0	0	0	1	-360	360;
3	36	0.0044	0.0108	0	0	0	0	0	0	1	-360	360;
36	37	0.064	0.1565	0	0	0	0	0	0	1	-360	360;
37	38	0.1053	0.123	0	0	0	0	0	0	1	-360	360;
38	39	0.0304	0.0355	0	0	0	0	0	0	1	-360	360;
39	40	0.0018	0.0021	0	0	0	0	0	0	1	-360	360;
40	41	0.7283	0.8509	0	0	0	0	0	0	1	-360	360;
41	42	0.31	0.3623	0	0	0	0	0	0	1	-360	360;
42	43	0.041	0.0478	0	0	0	0	0	0	1	-360	360;
43	44	0.0092	0.0116	0	0	0	0	0	0	1	-360	360;
44	45	0.1089	0.1373	0	0	0	0	0	0	1	-360	360;
45	46	0.0009	0.0012	0	0	0	0	0	0	1	-360	360;
4	47	0.0034	0.0084	0	0	0	0	0	0	1	-360	360;
47	48	0.0851	0.2083	0	0	0	0	0	0	1	-360	360;
48	49	0.2898	0.7091	0	0	0	0	0	0	1	-360	360;
49	50	0.0822	0.2011	0	0	0	0	0	0	1	-360	360;
8	51	0.0928	0.0473	0	0	0	0	0	0	1	-360	360;
51	52	0.3319	0.114	0	0	0	0	0	0	1	-360	360;
9	53	0.174	0.0886	0	0	0	0	0	0	1	-360	360;
53	54	0.203	0.1034	0	0	0	0	0	0	1	-360	360;
54	55	0.2842	0.1447	0	0	0	0	0	0	1	-360	360;
55	56	0.2813	0.1433	0	0	0	0	0	0	1	-360	360;
56	57	1.59	0.5337	0	0	0	0	0	0	1	-360	360;

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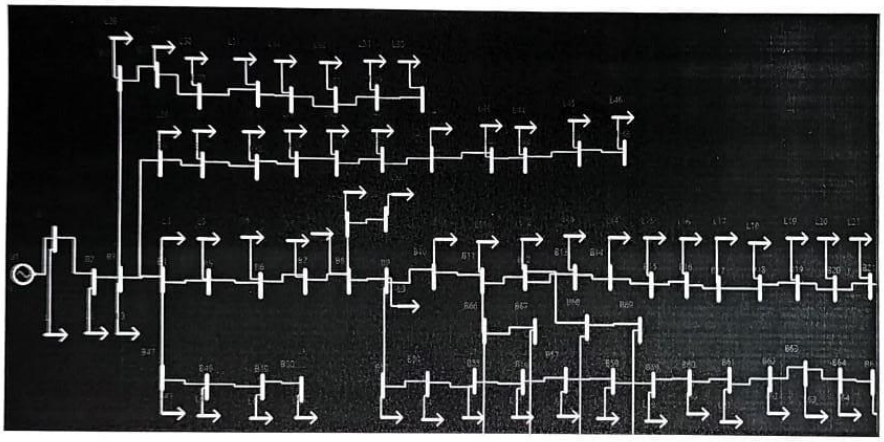
57	58	0.7837	0.263	0	0	0	0	0	0	1	-360	360;
58	59	0.3042	0.1006	0	0	0	0	0	0	1	-360	360;
59	60	0.3861	0.1172	0	0	0	0	0	0	1	-360	360;
60	61	0.5075	0.2585	0	0	0	0	0	0	1	-360	360;
61	62	0.0974	0.0496	0	0	0	0	0	0	1	-360	360;
62	63	0.145	0.0738	0	0	0	0	0	0	1	-360	360;
63	64	0.7105	0.3619	0	0	0	0	0	0	1	-360	360;
64	65	1.041	0.5302	0	0	0	0	0	0	1	-360	360;
11	66	0.2012	0.0611	0	0	0	0	0	0	1	-360	360;
66	67	0.0047	0.0014	0	0	0	0	0	0	1	-360	360;
12	68	0.7394	0.2444	0	0	0	0	0	0	1	-360	360;
68	69	0.0047	0.0016	0	0	0	0	0	0	1	-360	360;

Single Line Diagram Of Network:

Torrit View:



Standard View:

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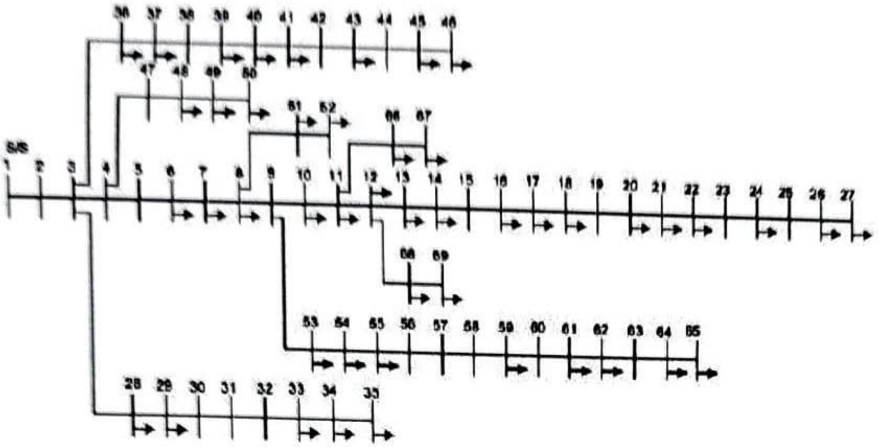
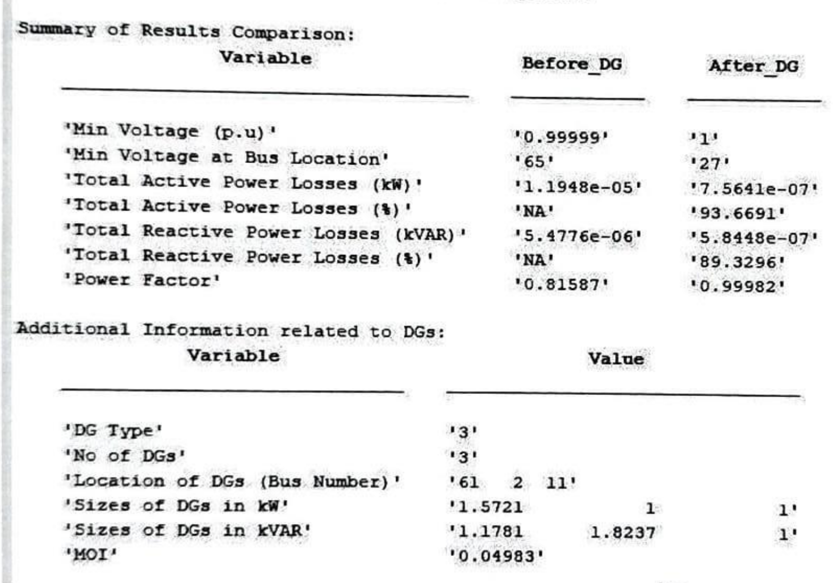


Results Summary Comparison Before & After D.G Placement:

1. **Results obtained from SEA HORSE OPTIMIZATION Algorithm:**



```
Summary of Results Comparison:
                    Variable                          Before_DG        After_DG
     ____________________________________________     __________     __________

     'Min Voltage (p.u)'                              '0.99999'       '1'
     'Min Voltage at Bus Location'                    '65'            '27'
     'Total Active Power Losses (kW)'                 '1.1948e-05'    '7.5641e-07'
     'Total Active Power Losses (%)'                  'NA'            '93.6691'
     'Total Reactive Power Losses (kVAR)'             '5.4776e-06'    '5.8448e-07'
     'Total Reactive Power Losses (%)'                'NA'            '89.3296'
     'Power Factor'                                   '0.81587'       '0.99982'

Additional Information related to DGs:
                 Variable                             Value
     _____________________________________     _____________________________________

     'DG Type'                                 '3'
     'No of DGs'                               '3'
     'Location of DGs (Bus Number)'            '61   2   11'
     'Sizes of DGs in kW'                      '1.5721          1              1'
     'Sizes of DGs in kVAR'                    '1.1781     1.8237              1'
     'MOI'                                     '0.04983'
```

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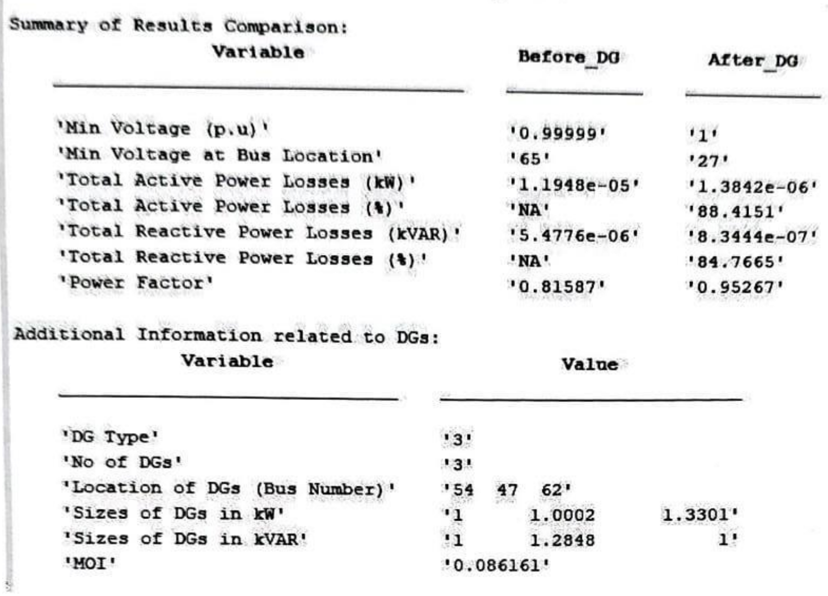
2. **Results obtained from ARTIFICIAL BEE COLONY Algorithm:**



```
Summary of Results Comparison:
                  Variable                           Before_DG         After_DG

    ___________________________________________     _____________     ____________

    'Min Voltage (p.u)'                              '0.99999'         '1'
    'Min Voltage at Bus Location'                    '65'              '27'
    'Total Active Power Losses (kW)'                 '1.1948e-05'      '1.3842e-06'
    'Total Active Power Losses (%)'                  'NA'              '88.4151'
    'Total Reactive Power Losses (kVAR)'             '5.4776e-06'      '8.3444e-07'
    'Total Reactive Power Losses (%)'                'NA'              '84.7665'
    'Power Factor'                                   '0.81587'         '0.95267'

Additional Information related to DGs:
               Variable                              Value

    ___________________________________     ________________________________

    'DG Type'                               '3'
    'No of DGs'                             '3'
    'Location of DGs (Bus Number)'          '54   47   62'
    'Sizes of DGs in kW'                    '1       1.0002       1.3301'
    'Sizes of DGs in kVAR'                  '1       1.2848            1'
    'MOI'                                   '0.086161'
```

Parameters Description:

1. **Bus Data Units and Format:**

1	bus number (positive integer)
2	bus type
	PQ bus = 1
	PV bus = 2
	reference bus = 3
	isolated bus = 4
3	Pd, real power demand (MW)
4	Qd, reactive power demand (MVAr)
5	Gs, shunt conductance (MW demanded at V = 1.0 p.u.)
6	Bs, shunt susceptance (MVAr injected at V = 1.0 p.u.)
7	area number, (positive integer)
8	Vm, voltage magnitude (p.u.)
9	Va, voltage angle (degrees)

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(-)		(bus name)
	10	baseKV, base voltage (kV)
	11	zone, loss zone (positive integer)
(+)	12	maxVm, maximum voltage magnitude (p.u.)
(+)	13	minVm, minimum voltage magnitude (p.u.

2. Generator Data Units and Format:

	1	bus number
(-)		(machine identifier, 0-9, A-Z)
	2	Pg, real power output (MW)
	3	Qg, reactive power output (MVAr)
	4	Qmax, maximum reactive power output (MVAr)
	5	Qmin, minimum reactive power output (MVAr)
	6	Vg, voltage magnitude setpoint (p.u.)
(-)		(remote controlled bus index)
	7	mBase, total MVA base of this machine, defaults to baseMVA
(-)		(machine impedance, p.u. on mBase)
(-)		(step up transformer impedance, p.u. on mBase)
(-)		(step up transformer off nominal turns ratio)
	8	status, > 0 - machine in service
		<= 0 - machine out of service
(-)		(% of total VAr's to come from this gen in order to hold V at
		remote bus controlled by several generators)
	9	Pmax, maximum real power output (MW)
	10	Pmin, minimum real power output (MW)
(2)	11	Pc1, lower real power output of PQ capability curve (MW)
(2)	12	Pc2, upper real power output of PQ capability curve (MW)
(2)	13	Qc1min, minimum reactive power output at Pc1 (MVAr)
(2)	14	Qc1max, maximum reactive power output at Pc1 (MVAr)
(2)	15	Qc2min, minimum reactive power output at Pc2 (MVAr)
(2)	16	Qc2max, maximum reactive power output at Pc2 (MVAr)
(2)	17	ramp rate for load following/AGC (MW/min)
(2)	18	ramp rate for 10 minute reserves (MW)
(2)	19	ramp rate for 30 minute reserves (MW)
(2)	20	ramp rate for reactive power (2 sec timescale) (MVAr/min)
(2)	21	APF, area participation factor

3. Branch Data Units and Format:

	1	f, from bus number
	2	t, to bus number

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(-) (circuit identifier)
3 r, resistance (p.u.)
4 x, reactance (p.u.)
5 b, total line charging susceptance (p.u.)
6 rateA, MVA rating A (long term rating)
7 rateB, MVA rating B (short term rating)
8 rateC, MVA rating C (emergency rating)
9 ratio, transformer off nominal turns ratio (= 0 for lines)
(taps at 'from' bus, impedance at 'to' bus,
i.e. if r = x = 0, then ratio = Vf / Vt)
10 angle, transformer phase shift angle (degrees), positive => delay
(-) (Gf, shunt conductance at from bus p.u.)
(-) (Bf, shunt susceptance at from bus p.u.)
(-) (Gt, shunt conductance at to bus p.u.)
(-) (Bt, shunt susceptance at to bus p.u.)
11 initial branch status, 1 - in service, 0 - out of service
(2) 12 minimum angle difference, angle(Vf) - angle(Vt) (degrees)
(2) 13 maximum angle difference, angle(Vf) - angle(Vt) (degrees)
(The voltage angle difference is taken to be unbounded below
if ANGMIN < -360 and unbounded above if ANGMAX > 360.
If both parameters are zero, it is unconstrained.)

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