POWER LOSS MINIMIZATION IN DISTRIBUTION POWER SYSTEM WITH DISTRIBUTED GENERATION USING NETWORK RECONFIGURATION

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Thesis submitted in fulfillment of the requirements
for the award of the
B. Eng (Hons.) Electrical Engineering (Power System)

Faculty of Electrical & Electronics Engineering

UNIVERSITI MALAYSIA PAHANG

JUNE 2022

ACKNOWLEDGEMENTS

I would like to acknowledge and give gratitude to some of my respected person. The completion of this project gives much pleasure. I would like to show gratitude to Dr. Norhafidzah Binti Mohd Saad, my course supervisor who giving continuous guidance and support for my Degree Study and Research.

I thank all the people for their help directly and indirectly to complete my project. Many thanks to the teaching and non-teaching staffs from College of Engineering for sharing their knowledge and lend us their facilities.

Last but not least, I express my sincere thanks to everyone who willing to spend their knowledge, idea and experience to supporting in the period of the project executing in order to complete the project in time.

ABSTRAK

Kapasiti penjanaan dan penghantaran sistem kuasa sedang dikuatkan oleh peningkatan permintaan tenaga. Prestasi sistem pengedaran menjadi merosot berpunca daripada peningkatan kerugian pengedaran dan penurunan magnitud voltan, dan perancangan sistem pengedaran yang lemah. Masalah-masalah ini boleh diatasi, dan prestasi sistem ditingkatkan dengan memasukkan Penjanaan Teraruh (DG) ke dalam sistem pengedaran dengan cara yang efisien. Tujuan laporan penyelidikan ini adalah untuk membentangkan kaedah gabungan yang berkesan berdasarkan “Backward-Forward Sweep Power Flow” (BFSPF) dan “Grey Wolf Optimizer” (GWO) dengan mengambil kira konfigurasi rangkaian dan kehadiran DG dengan tujuan mengurangkan kehilangan kuasa, meningkatkan voltan profil dalam rangkaian pengedaran, dan penilaian dari segi keberkesanan teknik pengoptimuman. Dalam rangkaian pengedaran sejajar, konfigurasi rangkaian digunakan ke dalam GWO dan mencari nilai terbaik untuk saiz DG secara serentak. Kesan teknik berdasarkan konfigurasi rangkaian dengan algoritma GWO untuk mencari kehilangan kuasa sebenar dan profil voltan dikaji. IEEE 33- sistem ujian bas dengan menambah lima suis pengikat digunakan untuk menggambarkan prestasi dan keberkesanan kaedah yang dicadangkan. Hasil kajian menunjukkan bahawa konfigurasi rangkaian dengan algoritma GWO adalah yang paling berjaya untuk mengurangkan kehilangan kuasa dan meningkatkan profil voltan dan mungkin boleh digunakan untuk merancang lebih awal dalam rangkaian pengedaran.

ABSTRACT

The power system's generating, and transmission capacities are being strained by rising energy demands. The performance of distribution system becomes degraded due to an increase in distribution losses and reduction in voltage magnitude, and bad planning of the distribution system. These issues may be addressed, and the system's performance improved by incorporating Distributed Generation (DG) into the distribution system in an efficient way. The purpose of this research report is to present an effective combination method based on Backward-Forward Sweep Power Flow (BFSPF) and Grey Wolf Optimizer (GWO) with considering network reconfiguration and the presence of DG with the purpose of minimizing real power loss, improving voltage profile in the distribution network, and evaluation in term of effectiveness of the optimization technique. In a radial distribution network, network reconfiguration is utilized into GWO and find the best value for DG size concurrently. The effect of a technique based on the network reconfiguration with GWO algorithm to find actual power losses and voltage profiles is examined. IEEE 33- bus test system by adding five tie line switch is used to illustrate the suggested method's performance and efficacy. The findings indicate that the network reconfiguration with GWO algorithm is the most successful for minimizing actual power loss and improving voltage profiles and that it may be used to plan ahead in distribution networks.

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LIST OF SYMBOLS

V_o	Voltage magnitude at sending end
V_i	Voltage magnitude at sending end of line
V_n	Voltage magnitude at receiving end
R_i	Branch resistance
X_i	Branch reactance
Y_i	Branch admittance
Z_i	Branch impedance
$P_{Loss,\ i}$	Real Power loss at bus i
$Q_{Loss,\ i}$	Reactive Power loss at bus i
P_i	Real Power flowing out of bus i
Q_i	Reactive Power flowing out of bus
P_{Li+1}	Real load Power at bus i+1
Q_{Li+1}	Reactive load Power at bus i+1
$P_{loss}(i,\ i+1)$	Real Power loss in the line section connecting buses i and i+1
$Q_{loss(i,\ i+1)}$	Reactive Power loss in the line section connecting buses i and i+1
$P_{Tloss(i,\ i+1)}$	Total Real Power Loss in the line section
$Q_{Tloss(i,\ i+1)}$	Total Reactive Power Loss in the line section
$\overrightarrow{D_p}$	Prey position vector
$\overrightarrow{X_n}$	Grey wolf position vector
$\vec{X}(t+1)$	Best search agent
$\vec{A}$	Position Vector Coefficient
α	Alpha
β	Beta
δ	Delta
ω	Omega

LIST OF ABBREVIATIONS

RDN	Radial Distribution Network
DG	Distribution Generator
GA	Genetic Algorithm
IEEE	Institute of Electrical and Electronics Engineering
KV	Kilo Volt
KVA	Kilo Volt Ampere
KVar	Reactive power
MV	Medium Voltage
MVar	Reactive Power in Mega watts
MW	Real power in Mega Watts
p.u	Per Unit
GWO	Grey Wolf Optimization
PSO	Particles Swarm Optimization
BPSO	Binary Particle Swarm Optimization
GOA	Grasshopper Optimization Algorithm
ALO	Ant Lion Optimizer
TLBO	Learning based Optimization
WOA	Whale Optimization Algorithm

CHAPTER 1

INTRODUCTION

1.1 Introduction

Power generation, transmission and distribution of electrical energy are the main function in electrical power system. The electricity system is the key to industrial progress as the rapid development of a country. It is very important to improve the living standards of the people in the country and the world. In general, a power system network consists of electrical components used to generate, transmit and distribute electrical power [1]. Power generation system is a network that distributes electricity to large areas. The three main parts have been divided in the power system. It is started from generation station that supply the power. Following that is the transmission line, which transmits power from the generation station to the load station. Finally, the distribution system will provide electricity to the residence and the industrial area.

Most of the distribution system feeders are constructed radially. The distribution substation supplies radial distribution feeder with a single voltage source. The main feeders are split into laterals and sub-laterals before connecting to the consumer switches. The feeders of the distribution system are made up of ties (normally open) and sectionalizing (normally closed) switches. In the case of a failure, these switches are utilised to improve distribution network consistency and will provide continuous energy for the majority of the load [2]. When a fault occurs in the distribution system, the normally open and normally closed switches are operated to disconnect the fault and change the load from one feeder to another. The operation of the normally open and normally closed switches in the distribution system is known as network reconfiguration. It is one of the methods that has been used to reduce distribution system losses.

Since electricity consumption has been increasing every year in the last decade, the amount of electrical energy needs to be increased and at the same time needs to control power losses. Power losses and voltage drop are directly proportional. If the load is increase, so the power losses and voltage drop also increase. In addition to this, it will affect the performance at distribution system causing inefficient during transmit power to the load [3]. This leads to an increase in operating costs to gain power generation for supporting those losses during transmitting to the load. In order to solve this problem, modern power systems and operation methods is considered as active distribution network by adding Distributed Generations (DG). In the power electrical system, reconfiguration of a distribution network is used for two main reasons which is load balancing and active power loss reduction. For load balancing means to transferring loads from a heavy-loaded feeder to a light-loaded feeder. Transferring load using changing the topological structure of the distribution system through a process called a reconfiguration process. The process involves modifying the network structure of distribution feeders in order to find an optimal radial network that minimises the active loss[4].

In order to realize the minimum load demand standard, DG units will be used in distribution network to optimize voltage profile by providing reliable and uninterrupted power supply. It also provide economic benefits such as minimum power loss with energy efficiency and load levelling [5]. Network reconfiguration and the use of DG in distribution networks are two separate methods. According to studies, choosing the wrong location and size for a DG it become make a result in higher system losses. In the past decade, many researchers have investigated network reconfiguration and DG deployment using several methodologies. Using the GWO Algorithm, this thesis provides a network reconfiguration strategy for a distribution network with the presence of DG by using backward-forward sweep power method. The proposed method can provide an ideal network distribution architecture while producing a suitable DG size and reducing power losses.

1.2 Problem Statement

In radial distribution network, there is high power loss which are reduces the quality of power supply. The power loss is due to the increased load will have an effect on the system voltage profile and result in loads not reaching their maximum rating. The research on optimal placement and sizing of DG in electrical distribution network systems using various optimization methods has caused major concern. This happens due to the highly increased power losses found within distribution feeders arranged in a radial pattern and primarily fed by a utility substation. Distribution networks have been shown to have significant voltage drop due to high R/X ratio and result in significant power losses along feeders.

Other than that, total power losses due to DG reconfiguration and installation in the distribution network can be increased. Also, the voltage profile cannot be improved due to the DG size and placement being performed improperly. The network reconfiguration and DG power allocation operate simultaneously can produce a more satisfying result than operate each process separately. Previous distribution system research is focused on a specific improvement. It may not be effective for overall distribution network efficiency.

Most of the optimization method used to solve the problem focus on reducing power loss and improving voltage profile. However, ignoring the issue of optimization process efficiency will take a long time to attain the objective value. The execution time is longer and less effective due to a poor combination of optimization method. Hence, based on the mentioned issue above, it became important to analyse this field of study.

1.3 Objective

The objectives of this research work are as follows;

I. To reconfigure radial distribution network in distribution system by using backward-forward sweep load flow method.

II. Optimal placement and sizing of the distributed generators for reducing of total power loss and voltage profile improvement using GWO algorithm.

III. To compare and evaluate the result obtained by GWO with MIOGA and PSO.

1.4 Scope of Project

The scope of project includes carrying out a radial load flow analyse on standard IEEE 33-bus distribution network systems. An effective method of radial distribution system called backward-forward sweep method will be use for the load flow solutions. In addition, to analyse the impact of network reconfiguration using backward-forward sweep power flow for power losses and voltage profile in radial distribution network. It also includes the implementation of an algorithm for optimal size and location of the DG system in distribution networks using Grey Wolf Optimization (GWO) approach.

The aim of this research project is GWO algorithm method combined with backward-forward sweep load flow for the minimization of total power loss and voltage improvement. Optimization technique the GWO will be compared to the MIOGA and PSO in terms of the effectiveness of the algorithm.

1.5 Thesis Outline

In this thesis, chapter one contains an overview of the proposed research where a brief explanation about introduction of overall research works. The major problem statement, objectives, and scope of work of the study have been emphasised to provide some insight into the likely goal that will be realised at the end of this research while adhering to the scope of work as stated in this chapter.

Chapter two describes literature review of electric distribution system. This Chapter also includes an explanation of the power flow analysis method, network reconfiguration, Distributed Generation (DG) and optimization technique

Chapter three contains the main methodology and approach adopted in this research so as to achieve the main target. This Chapter described the method solution and optimization technique involved in the methodology. The Backward-Forward Sweep Power Flow (BFSPF) approach in combined with GWO algorithm is used for this research.

Chapter four contains all case output test system simulation results, analysis, algorithm output result, and finally output result discussion. This chapter also shows the optimization results, which include the DG size and location, total power losses, critical voltage magnitude, and effectiveness of the algorithm technique.

Chapter five contains the final conclusion that the result of the investigation meets the objective or not, observations for future areas of research and also possible recommendations on how to improve the system that can make it better.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter explained based on the scope that are covered in this project and it is separated by four main topic which are power flow solution method, network reconfiguration, Distributed Generation (DG) and Grey Wolf Optimization (GWO). All the main topics referred based on the study from the related journals and conferences.

2.2 Power Flow Analysis Method

Various numerical analysis approaches have been used to solve load flow analysis problems throughout the past three decades. The Gauss-Seidel, Newton-Raphson, and Fast Decoupled methods are the most often utilised iterative algorithms. From the comparison between Gauss-Seidel method with Newton-Raphson method where Gauss-Seide method takes less time to complete one iteration. The Newton-Raphson concept states that fewer mathematical operations which is the calculation of the Jacobian are required in completing each iteration. Because of its quadratic convergence features, the Newton-Raphson approach has a faster rate of convergence. The number of iterations required by the Gauss-Seidel technique increases as the network size increase. In example, the more buses in the network, the longer it takes for the approach to discover a solution [2]. The Fast Decouple method takes longer to reach a solution. It is important to know that the Fast Decouple method searches for the answer using specific assumptions. With the added benefit of lower computational requirements such as memory and processing time, Fast Decouple also make it as fast as the Newton-Raphson technique.

Furthermore, both the Newton-Raphson and Fast Decouple method are effective and may be used at huge and complicated networks [17]. A load flow analysis is a very important tool for planning and analysing a power system steady state operation. The load flow circuit is used to model the power system, which includes generators, transmission lines, and distribution lines. Power flow studies use a systematic mathematical approach to calculate bus voltages, phase angles, and active and reactive power flows through various branches. In the distribution system it bases on several special features fall in the category of ill-condition [6] such as;

- Radial or weakly meshed networks.
- High R/X ratios.
- Multi-phase, unbalanced operation.
- Unbalanced distributed load.
- Distributed generation.

Newton Raphson and other transmission system algorithms have ineffective with distribution networks due to the mentioned factors. To study the distribution network, the backward-forward sweep power flow method is used. Difference from Newton-Rapson method, this method does not require a Jacobian matrix. However, for modern active distribution networks are used traditional backward-forward sweep power flow method is effective.

2.2.1 Backward-Forward Sweep Power Flow Method

Forward-backward sweep power flow method generally use the radial network topology which is includes forward and backward sweep processes. In this type of algorithm, the forward sweep is the calculation of node voltage from the sending end to the far end of the feeder. Besides, the backward sweep is the calculation of branch current and power from the far end to the sending end of the feeder. In addition to the branch current and total power, some methods compute node voltages in backward sweeps [7].

The forward sweep is generally a voltage drop calculation with current or power flow changes. The nodal voltages are updated in a forward sweep from the first node bus to the last node bus. The forward propagation method is used to determine the voltages at each node, starting at the feeder source node. The voltage of the feeder substation is set to its real value. The effective power in each branch remains constant during forward propagation to the value obtained in backward propagation [8].

The backward sweep is basically a current or power flow solution with possible voltage updates. It starting from the branches in the last node bus and moving towards the branches connected to the root node. Backward propagation computes the updated effective power flows in each branch by using the node voltages from the previous iteration. It means that during backward propagation, the voltage values obtained in the forward direction are maintained constant. Power flows in each branch are carried backward along the feeder using the backward direction is updated. This means that backward propagation begins at the far end node and works its back direction to the source node. Furthermore, it is generally known that the forward-backward sweep method has three primary types that differ from one another based on the type of electric values calculated at each iteration, starting from the terminal nodes and moving up to the source node.

Lastly, the next iteration is determined by comparing the estimated voltages in previous and current iterations. If the voltage mismatch is less than the specified tolerance, 0.0001, convergence can be completed. Otherwise, new effective power flows in each branch are calculated using the current computed voltages in a backward propagation, and the method is repeated until the solution is converged.

2.3 Network Reconfiguration and DG

Network reconfiguration and DG placement are the most popular approaches for improving voltage stability and reducing power loss in power distribution networks [5]. To maximizing the benefits while minimizing the impact on the power system, the network structure, placement, and size of DG units should be optimised. As a result, finding the best way to combine these two challenges becomes a substantial and complicated process. The process of changing the topology of a network by changing the open and closed status of switches in order to find a radial operating structure that reduces losses and increases voltage stability while maintaining operating constraints is known as network reconfiguration. For the past two decades, many researchers have used various techniques to solve network reconfiguration problems [5].

2.4 Distribution Generation

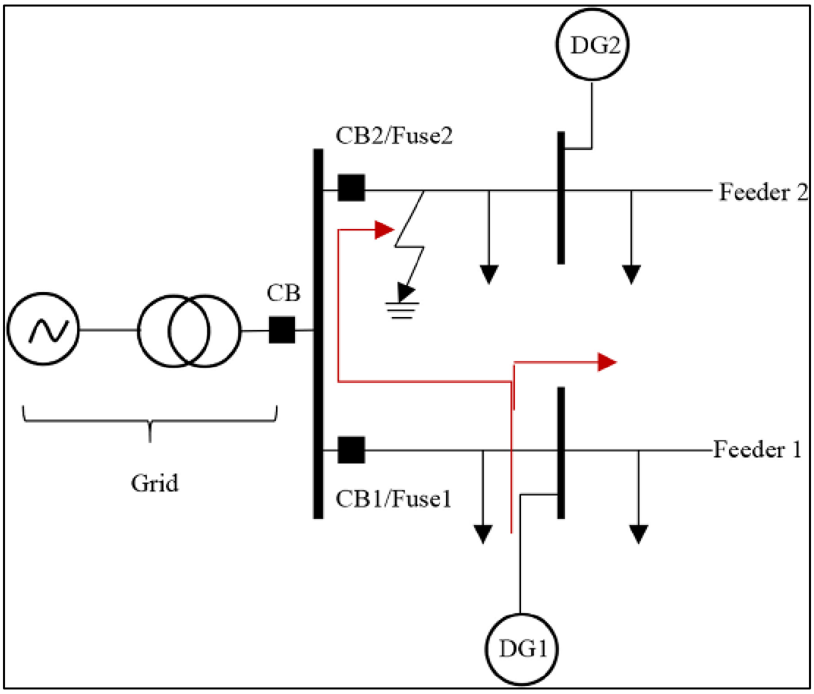

Figure 2.1 Transmission System with DG

As shown in Figure 2.1, the transmission system with DG is rearranging different switches that connect or disconnect the system branches is known as distribution system reconfiguration. This reconfiguration system is used to achieve a radial structure that increases overall system performance and efficiency. With the increasing of the Distributed Generation (DG), the system parameters are more likely to change frequently. As a result, the requirement for network reconfiguration grows as the system flexibility improves and make it easier to deal with operational variations.

Furthermore, distributed generation is a suitable solution for solving the ever-increasing environmental concerns and energy demand [9]. Small generators are connected into a distribution system to achieved the required level of load demand, improving the voltage profile, maximising of system equipment, delivering sustainable and cost-effective benefits such as decreased power losses and increased power efficiency. It is important because it uses both renewable and non-renewable energy sources. Placement distributed generation has a significant impact on voltages, load demand, power loss, and system reliability, make it an important issue for power system distribution system planning [10]. The placement of the DGs is important to the system's efficiency.

The main reasons to use DGs in power distribution are power efficient, competition policy, investments of energy sources. Presence of sector generating station that will ease of finding locations for smaller generators. Also affect in term of the lower capital costs for smaller plants and proximity of the generation station to heavy loads which is can reduce transmission costs. When the DG was added to the network, it can give a variety of advantages. Some of the advantages include reduced power loss, lower energy undelivered costs, and the prevention of network growth [11][12]. Other advantages include lower peak load running costs, a better voltage profile, and higher load factors [13]. Besides, DG also can have both positive and bad effects on the network in addition to providing advantages. These effects include frequency deviation and voltage deviation [14]. Another effect that may occur is an increase in power losses [11][15].

2.4.1 DG Location and Sizing

Based on previous studies on the best location of DG in distribution systems, the DG allocation is normally a complicated optimization problem involving the best placement of DG in existing distribution networks. Besides, optimization problems also involve maintaining a number of technical, economic, and environmental constraints. The best location and size of DG can be obtained in an excellent optimization. Because the problem is nonlinear, the DG planning and optimization problem is normally difficult to solve using traditional mathematical methods [16]. If the size of DG is further increase, the losses also increase. It is also important to recognise that DG placement is important for minimising losses. In addition, the maximum size of DG should have a limit in order for it to be consumed within the distribution substation range.

2.5 Optimization Technique

There are numerous algorithm approaches for determining the lowest or maximum goal function. The algorithm below has been widely used in the application of an electric power system to solve various problems.

I. Grey wolf Optimization (GWO)

II. Genetic Algorithm (GA)

III. Particle Swarm Optimization (PSO).

2.6 Grey Wolf Optimization (GWO) Technique

GWO algorithm is an optimization approach that is used to minimise or maximise an objective function of the power system problem. The algorithm sections provide GWO explanations.

2.6.1 Grey Wolf Optimization (GWO) in Natural Behaviour

Syedali Mirjalili et al. [17] proposed the "Grey Wolf Optimizer" in 2014, a new population-based meta-heuristic optimization approach (GWO). It simulates the leadership structure and hunting procedure of grey wolves, which are classified as apex predators which are like to live in groups of 5–12 pack members.

2.6.2 Grey Wolf Optimization (GWO) Techniques

GWO is one of the optimization techniques that are increasing rapidly to different area of electric power systems. Moreover, GWO is an algorithm that will optimizes a problem with trying to get the best score base on social hierarchy with regard to the constraints. Following that, all grey wolves in a pack respond to the dominant social hierarchy represented in Figure 2.2 and the level of the hierarchy decreasing from search agents to wolves. Alphas (α) are the highest rank in the grey wolf hierarchy which are the leaders. Alphas (α) also makes all decisions regarding sleeping arrangements, hunting, waking hours, and so forth. All other pack members must follow these commands. Beta (β) is the second highest level and is subservient to aides the pack leader in decision-making and enforces a's directives. Delta (δ) serves as a feedback channel for wolves reporting. Finally, omega (ω) is the follower and the lowest in the hierarchy.

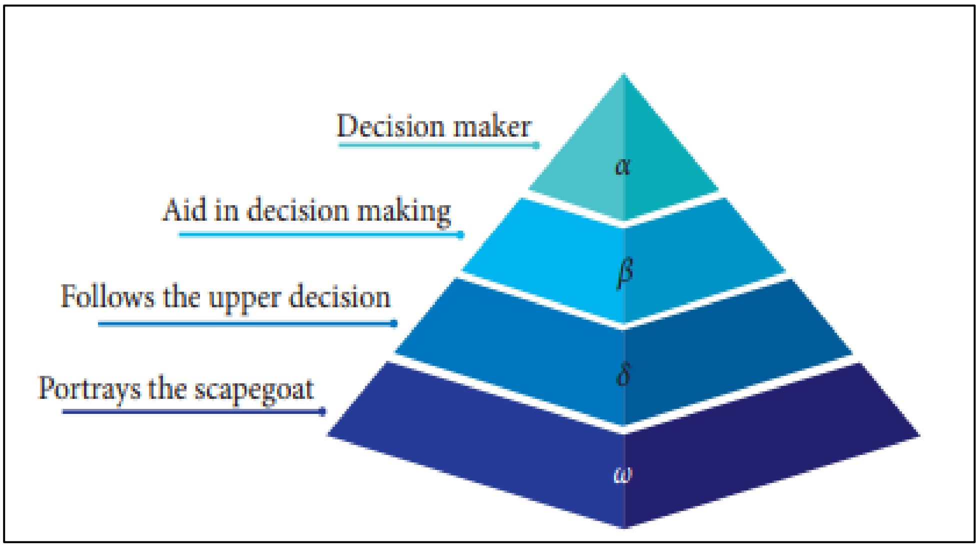

Figure 2.2 Social Hierarchy

The mathematical modelling of the GWO can be outlined as follows:

I. Social hierarchy: For GWO, alpha (α) is the best match, followed by beta (β) and delta (δ), which are the second and third best answers, respectively.

II. Prey encirclement: Prey encirclement can be stated mathematically as follows:

$$\overrightarrow{D_p} = | \overrightarrow{C_n} \cdot \overrightarrow{X_p} - \vec{X}(t) | \quad 2.1$$

$$\overrightarrow{X_n} = | \overrightarrow{X_p}(t) - \overrightarrow{A_n} \cdot \overrightarrow{D_p} | \quad 2.2$$

- where A and C are coefficient vectors, t is the current iteration, X_n is the grey wolf position vector, and X_p is the prey position vector. Meanwhile, A and C are vectors that may be computed using the formulae below:

$$\vec{A} = 2\vec{a} \cdot \vec{r} - \vec{a} \quad 2.3$$

$$\vec{C} = 2 \cdot \overrightarrow{r_2} \quad 2.4$$

III. Hunting: Hunting is guided by, and the capacity to identify and encircle prey. The positions of the other search agents will be updated in accordance with the position of the best search agent. This behaviour is expressed by the following equations:

$$\vec{X}(t+1) = \frac{(\overrightarrow{X_n} + \overrightarrow{X_{n+1}} + \overrightarrow{X_{n+2}})}{3} \quad 2.5$$

IV. Attacking the prey: Attacking the prey: grey wolves will attack the prey when it comes to a halt in its journey. Each repetition lowered from 2 to 0 for every iteration.

V. Searching for prey: GWO algorithm's exploration is formed based on the location wolves. During the hunt for prey, the wolves separate and then converge to attack the target.

2.7 Overview on Power Flow Analysis and Optimization Methods

Table 2.1 Overview on Power Flow Analysis and Optimization Methods

Year	**Author**	**Title**	**Problem/Suggestion**	**Solution**	**Method**	**Note**	**Gap**
2019	Kirithikaa Sampath, Srividhya Pattabiraman, Mounika Kannan, Girish Ganesan Ry and Narayanan Ky	Power Loss Minimization in Radial Distribution System through Network Reconfiguration	The system's power loss has increased due to unexpected loads and growing power demand.	The BPSO technique improves convergence characteristics, and the effect of parameters on obtaining the best solution is analyzed.	Binary Particle Swarm Optimization (BPSO) method	Loss reduction percentage is found to be 31.48% and 56.1731% after Reconfiguration for 33-buses and 69-buses respectively	This article mainly focuses on the BPSO approach, which combines an optimum configuration objective function with a multi-objective framework to increase system dependability and performance.

2020	Daniel Pál, Ľubomír Beňa, Jakub Urbanský, Maksym Oliinyk	A power flow analysis method for the integrated electricity-heat system in distribution network based on forward/backward iterations	The ineffectiveness operation of power system affected to the power losses and voltage stability	Different criteria such as voltage profile, power losses, and stability index have been evaluated for each bus with and without DG installation.	Backward-forward sweep algorithm method	DG placement was affected into the voltage profile, real power losses and voltage stability index.	This researcher is not comparing for the effectiveness of the optimization technique.
2020	N.Vijayalaksmi and Dr. K. Gayathri	Optimal placement of DG Units and Network Reconfiguration for Power Loss Minimization and Voltage Profile Improvement in Distribution Network	Improving voltage stability and minimizing power loss is a critical optimization challenge in the radial distribution system.	ALO algorithm has implemented for optimal network reconfiguration	ALO algorithm method	ALO is the most accurate and best method for solving complicated optimization problems in distribution networks.	This researcher is not comparing for the effectiveness in term of the time taken for optimization technique.

2022	Shashank Gupta, Mahiraj Singh Rawat, Tripurari Nath Gupta	A Comparison of Heuristic Optimization Techniques for Optimal Placement and Sizing of DGs in Distribution Network.	Load energy demand has expanded rapidly in radial and poorly meshed networks, increasing power loss and voltage drops.	This article has been solved with a comparison of active power loss reduction techniques.	Particle Swarm Optimization (PSO), Teaching Learning Based Optimization (TLBO), Grey Wolf Optimization(GWO), Whale Optimization Algorithm(WOA).	All the method was efficiency into the minimize power losses in the RDN	This article is not used combined load flow analysis method with optimization method.
2018	Hanan Hamour, Salah Kamel, Hussein Abdel-mawgoud, Ahmed Korashy, Francisco Jurado	Distribution Network Reconfiguration Using Grasshopper Optimization Algorithm for Power Loss Minimization	Since the distribution system operates at low voltages, there is an increasing amount of power loss in the network.	The method mathematically simulates feeder reconfiguration based on grasshopper action in nature and it is then used to determine the ideal network configuration.	Grasshopper Optimization Algorithm.	Power losses reduce until 38.0074%.	This article is not compared to the other optimizations to prove that the effectiveness

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter will provide details of the methodology that is being used to complete this project. The experiments are carried out by using MATLAB. After a few iterations, MATLAB will perform all the calculations. All the convergence are completed after the value of tolerance is less than 0.0001 for Backward-Forward Sweep Power Flow (BFSPF).

3.2 Theoretical proposed method

This project proposes network reconfiguration and the utilisation of DG to RDN. To achieve the objective, it needs to use method backward-forward sweep for load flow analysis and Grey Wolf Optimization (GWO) to identify the optimal placement and size of DG. Next, four cases are performed and will be investigated. The detail each case will be explanation at Section 3.4.

I. Case 1: case study without considering network reconfiguration and without DG

II. Case 2: case study with considering network reconfiguration and without DG

III. Case 3: case study without considering network reconfiguration and with DG

IV. Case 4: case study with considering network reconfiguration and with DG

3.3 Method Solution

3.3.1 Methodology Overview

The block diagram show in Figure 3.1 indicates the entire process of the planning of radial distribution network with distributed generation.

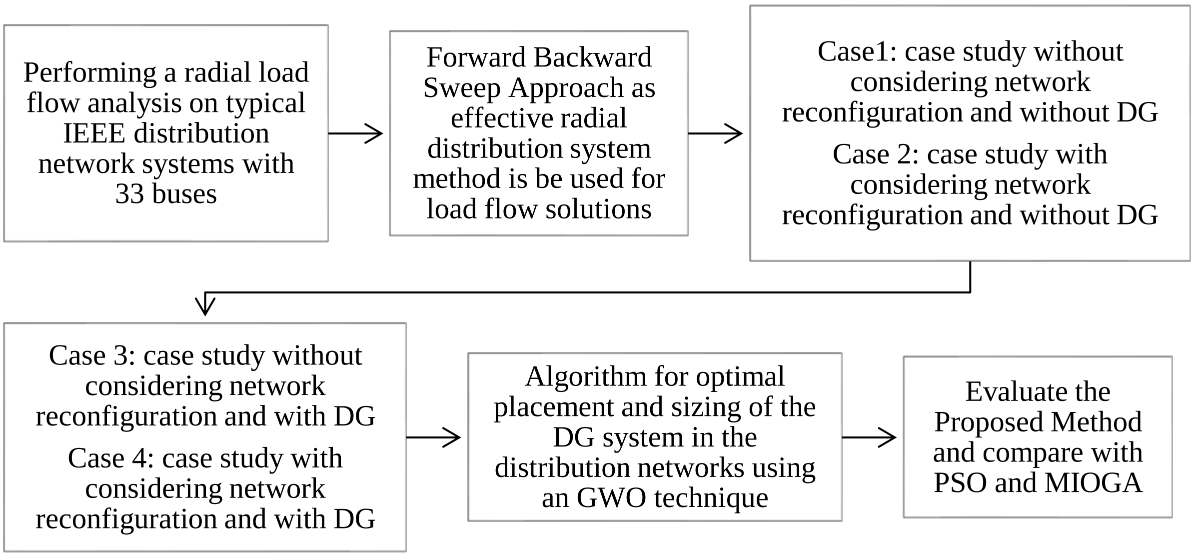

Figure 3.1 Block diagram for methodology

The data from the radial distribution network such as bus data, line data and tie line data are utilised as input to solve the power flow problem using the backward-forward sweep power flow technique. The different cases are investigated by considering network reconfiguration and DG placement. Case 1 is case study without considering network reconfiguration without DG. Case 2 is case study with considering network reconfiguration and without DG. Case 3 is case study without considering network reconfiguration and with DG. Case 4 is case study with considering network reconfiguration and with DG. The output from backward-forward power flow which are total power loss and voltage magnitude is use in optimization method using GWO algorithm.

The optimal size and location of the DG will be determined and return back to input if did not meet the termination criteria. The effectiveness GWO method are evaluated and compare with the PSO and MIOGA as a benchmark.

3.3.2 Problem Formulation

Figure 3.2 show the single line diagram of radial distribution network from sending end to receiving end.

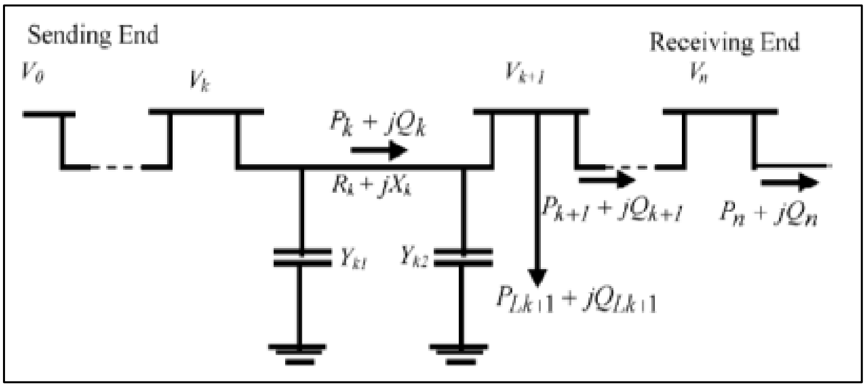

Figure 3.2 Single Line Diagram of Radial Distribution Network

The following method of simple iterative equations derived from the single-line diagram shown in figure 3.2 are used to calculate power flows in a distribution system. The voltage magnitude and power losses of the 33-bus system can be determined using the power flow analysis. The mathematical equation can be expressed as following;

$$P_{k+1} = P_k - P_{Loss,k} - P_{Lk+1} \qquad 3.1$$

$$Q_{k+1} = Q_k - Q_{Loss,k} - Q_{Lk+1} \qquad 3.2$$

Where;

P_k – Real power flowing out of bus

Q_k – Reactive power flowing out of bus

P_{Lk+1} – Real Load power at bus k+1

Q_{Lk+1} – Reactive load power at bus k+1

The power loss in the line section connecting buses k and k+1 may be computed as;

$$P_{loss}(\mathrm{k}, \mathrm{k}+1) = R_k \frac{P_k^2 + Q_k^2}{V_k^2} \qquad 3.3$$

$$Q_{loss}(\mathrm{k}, \mathrm{k}+1) = X_k \frac{P_k^2 + Q_k^2}{V_k^2} \qquad 3.4$$

where;

P_{Loss} (k, k+1) – Real power loss in the line section connecting busses k and k+1

Q_{Loss} (k, k+1) – Reactive power loss in the line section connecting busses k and k+1

The total power loss of the feeder, $P_{T,\,loss}$ may then be determined by summing up the losses of all line sections of the feeder, which is given as

$$P_{T,loss}(\mathrm{k}, \mathrm{k}+1) = \sum_{k=1}^{n} P_{loss}(k, k+1) \qquad 3.5$$

$$Q_{T,loss}(\mathrm{k}, \mathrm{k}+1) = \sum_{k=1}^{n} Q_{loss}(k, k+1) \qquad 3.6$$

Where;

$P_{T,\,Loss}$ (k, k+1) – Total real power loss in the line section

$Q_{T,\,Loss}$ (k, k+1) – Total reactive power loss in the line section

3.3.3 Backward Forward Sweep Power Flow Method

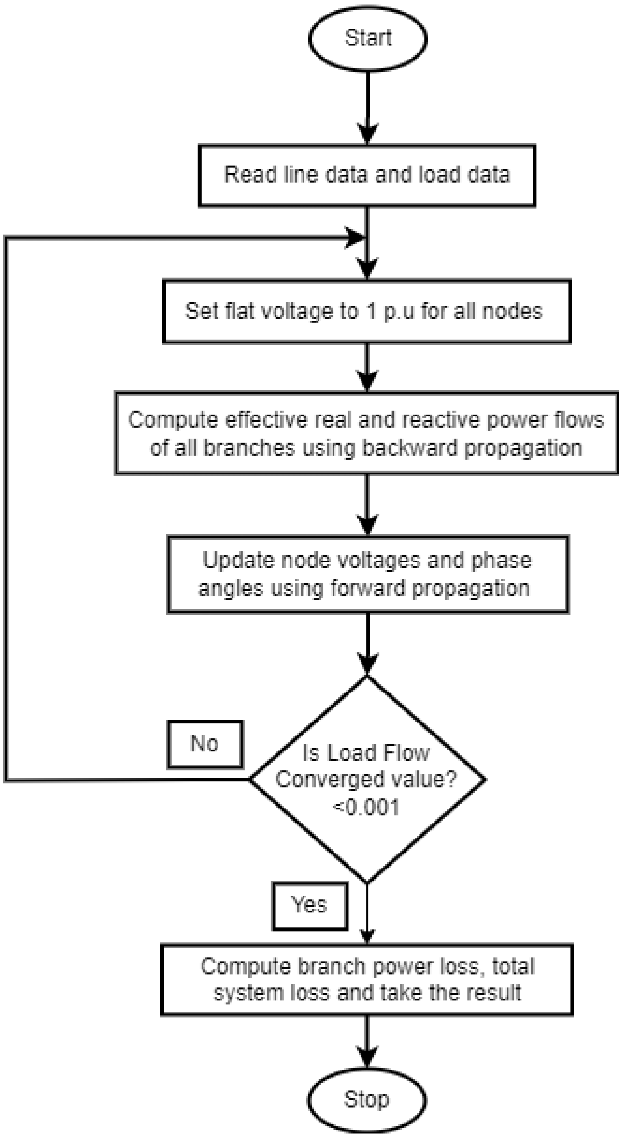

Figure 3.3 Backward-Forward Sweep Power Flow Method

The backward-forward sweep power flow method which are implemented to support for the analysis of the iterative process' convergence. Consider Figure 3.3, a branch is connected between the node ‘k’ and ‘k+1’. The effective active (P_k) and reactive (Q_k) powers that of flowing through branch from node ‘k’ to node ‘k+1’ can be calculated backwards from the last node and is given as,

$$P_k = P'_{k+1} + R_k \frac{P'^2_{k+1} + Q'^2_{k+1}}{V_k^2} \quad 3.7$$

$$Q_k = Q'_{k+1} + X_k \frac{P'^2_{k+1} + Q'^2_{k+1}}{V_k^2} \quad 3.8$$

Where;

$P'_{k+1} = P_{k+1} + P_{L,\, k+1}$

$Q'_{k+1} = Q_{k+1} + Q_{L,\, k+1}$

P_{k+1} and Q_{k+1} are the effective real and reactive power flows from node 'k+1', and P_{Lk+1} and Q_{Lk+1} are the loads connected at node 'k+1'.

Each node's voltage magnitude and angle are calculated in the forward direction. Consider the voltages V_k k at node 'k' and V_{k+1} k+1 at node 'k+1'. The current flowing through the branch with an impedance of $Z_k = R_k + X_k$ connected between 'k' and 'k+1' is given as,

$$I_k = \frac{(V_k < \delta_k) - (V_{k+1} < \delta_{k+1})}{Z_k} \quad 3.9$$

The magnitude and the phase angle equations can be used recursively in a forward direction to find the voltage and angle respectively of all nodes of radial distribution system.

Initially, all nodes are considered to have a flat voltage profile is 1.0 p.u. With the updated voltages at each node, the branch powers are determined iteratively. Power summation is done in the backward propagation while voltages are determined in the forward propagation in the proposed load flow method. The forward-backward operation is repeated until the direction is found to be converging. The following is an example of a convergence condition:

I. There should be voltage variations between any forward and backward buses such that the differences are fewer than the stated errors.

II. The difference between the P_{Loss} values in the forward and backward directions should be less than the defined error value.

3.3.4 Grey wolf Optimization (GWO)

The general flowchart for the Grey Wolf Optimization (GWO) algorithm can be seen in figure 3.4.

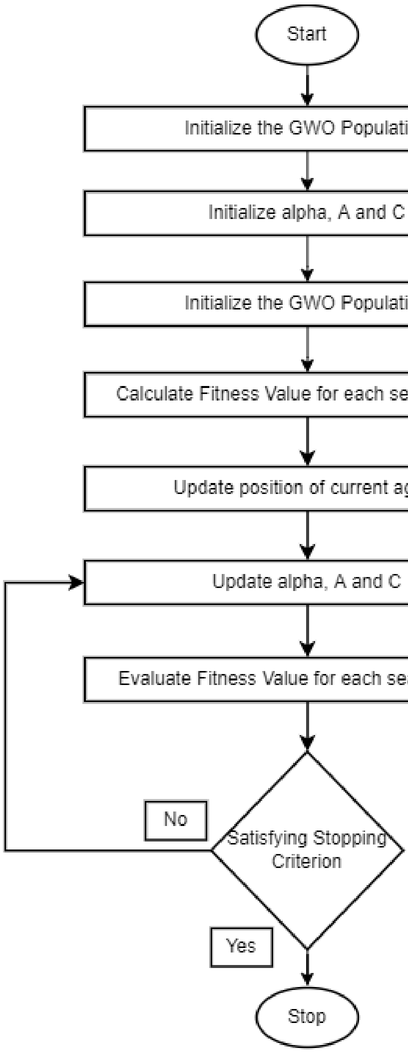

Figure 3.4 Flowchart for GWO Algorithm

Figure 3.4 illustrates and explains the GWO algorithm procedures for typical flow charts step by step.

Step 1: In initialization, are included the parameters of GWO and the constraint that are used for their project.

Step 2: Set up the population, number of variables, variable bounds, and α, β and δ locations.

Step 3: Calculate fitness of each search agent/wolf, choose the first three best wolf and save as α, β and δ in turn.

- Xα= 1st best agent
- Xβ= 2nd best agent search agent
- Xδ= 3rd best search agent

Step 4: Update the position of current search agent. Xα, Xβ, Xδ are calculated by using the formula from equation (2.5).

Step 5: Update a, A and C by using the formula from equation (2.2) and Evaluate fitness value which is evaluates how close a given solution is in the optimum solution of desired problem and determine how fit a solution is.

Step 6: Stop the objective search in the searching process if the solution convergence condition is fulfilled. The α score is assigned to best score corresponding to the best position.

3.4 Design Development

3.4.1 Test Case for Investigation

Figure 3.5 show an IEEE 33-bus radial distribution network with four lateral feeders. Substation voltage is 12.66 kV are used in this system. For the bus 1 is a slack bus, whereas the others are load bus.

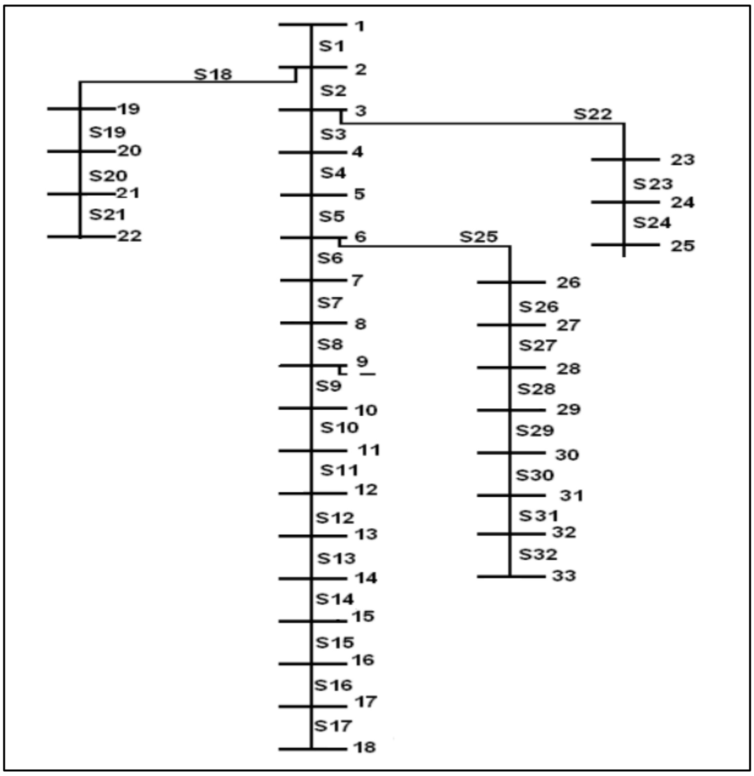

Figure 3.5 IEEE 33-Bus Radial Distribution Network

3.4.2 Bus Data and Line Data

Table 3.1 shows bus data which is real power, P and reactive power, Q for each bus from bus 1 to bus 33 based on load data. The line data which is value of resistance, R and the impedance, X from sending bus to the receiving bus.

Table 3.1 Bus data and line data

Bus No	Real Power, P (KW)	Reactive Power, Q (KVAR)	Sending Bus	Receiving Bus	R (Ω)	X (Ω)
1	-	-	1	2	0.0922	0.0470
2	100	60	2	3	0.4930	0.2511
3	90	40	3	4	0.3660	0.1864
4	120	80	4	5	0.3811	0.1941
5	60	30	5	6	0.8190	0.7070

6	60	100	6	7	0.1872	0.6188
7	200	100	7	8	1.7114	1.2351
8	60	20	8	9	1.0300	0.7400
9	60	20	9	10	1.0440	0.7400
10	45	20	10	11	0.1966	0.0650
11	60	30	11	12	0.3744	0.1238
12	60	35	12	13	1.4680	1.1550
13	120	35	13	14	0.5416	0.7129
14	60	80	14	15	0.5910	0.5260
15	60	10	15	16	0.7463	0.5450
16	60	20	16	17	1.2890	1.7210
17	60	20	17	18	0.7320	0.5740
18	90	40	2	19	0.1640	0.1565
19	90	40	19	20	1.5042	1.3554
20	90	40	20	21	0.4095	0.4784
21	90	40	21	22	0.7089	0.9373
22	90	40	3	23	0.4512	0.3083
23	90	50	23	24	0.8980	0.7091
24	420	200	24	25	0.8960	0.7011
25	420	200	6	26	0.2030	0.1034
26	60	25	26	27	0.2842	0.1447
27	60	25	27	28	1.0590	0.9337
28	60	20	28	29	0.8042	0.7006
29	120	70	29	30	0.5075	0.2585
30	200	600	30	31	0.9744	0.9630
31	150	70	31	32	0.3105	0.3619
32	210	100	32	33	0.3410	0.5302
33	60	40	-	-	-	-

3.4.3 Reconfiguration Network

Five tie-line switches are added to the IEEE 33-bus radial distribution network for considering network reconfiguration, as shown in Figure 3.6. There are five tie switches and 32 sectionalizing switches in the test system. The normally closed sectionalize switches are numbered of branch 1 to branch 32 in the network, while normally open tie-switches are bus numbered of branches 33 to branches 37. This method is tested on the 33–bus system to show the efficiency after considering the network reconfiguration. The following are the details of the 33–bus system:

I. Number of buses – 33

II. Number of branches – 37

III. Number of tie lines – 5

IV. Tie lines – S33, S34, S35, S36, S37

V. Total real power – 3715 KW

VI. Total reactive power – 2300 KVAR

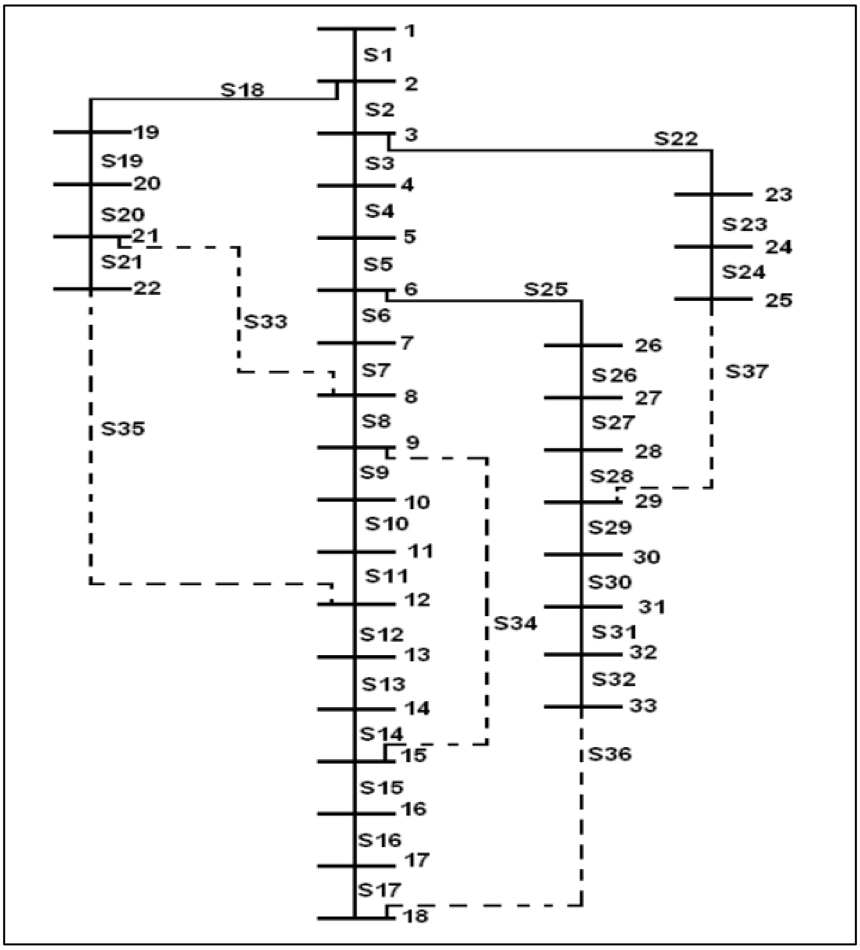

Figure 3.6 IEEE 33-Bus Radial Distribution Network Considering Network Reconfiguration

Table 3.2 Tie Line Data

Tie Lines	Sending Bus	Receiving Bus	R (Ω)	X (Ω)
33	8	21	2.0000	2.0000
34	9	15	2.0000	2.0000
35	12	22	2.0000	2.0000
36	18	33	0.5000	0.5000
37	25	29	0.5000	0.5000

According to Table 3.2 show tie line data has been added into the IEEE 33-bus radial distribution network. Tie line data at number of branches 33 to branches 37 which is value of resistance, R and the impedance, X from sending bus to the receiving bus. With added tie data, the topology change occur which is normally open and normally closed are operated to transferring heavy load to the light load. This operation will be affected to the increasing voltage profile and reducing power losses.

3.4.4 Case 1: Case Study without Considering Network Reconfiguration and without DG

In Figure 3.3 of Section 3.3, a flowchart is being used for the Case 1. The bus data and line data are used from Table 3.1. The decision is based on the load flow convergence value are must be less than 0.0001 in order to finish the backward-forward sweep power flow method. Otherwise, the operation method of backward-forward sweep power flow is restarted to the set voltage at all node.

3.4.5 Case 2: Case Study with Considering Network Reconfiguration and without DG

The Backward-Forward Sweep Power Flow (BFSPF) method is used to evaluate the load flow in the radial distribution network with network reconfiguration. The flowchart for Case 2 is depicted in Figure 3.7.

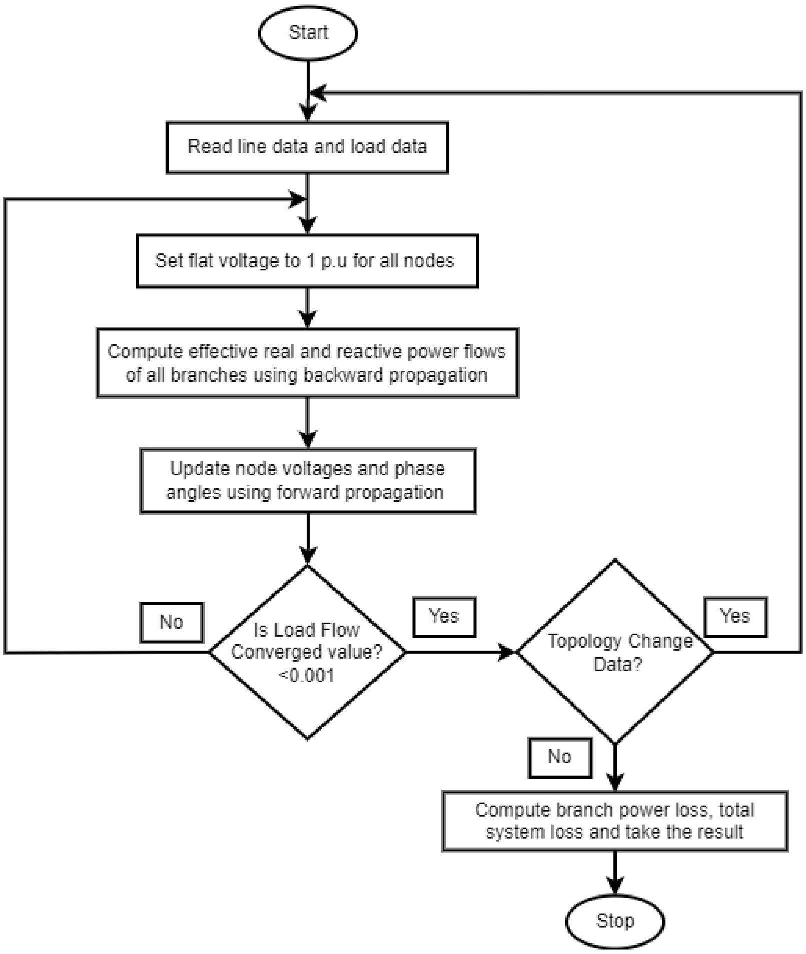

Figure 3.7 Flowchart for Case 2

Figure 3.7 is a flowchart that has been utilised with the parameters specified in Table 3.2 to use the IEEE 33-bus data for validate the proposed method for Case 2. There is a case study with network reconfiguration and without DG. This flow chart combines two decisions areas which is load convergence value must less than 0.0001 and topology change data. Topology change is operated when the five tie line data is added into the IEEE 33-bus data. The topology change data also known the network reconfiguration.

3.4.6 Case 3: case study without considering network reconfiguration and with DG

The flowchart for the optimization method without considering network reconfiguration can be seen in Figure 3.8.

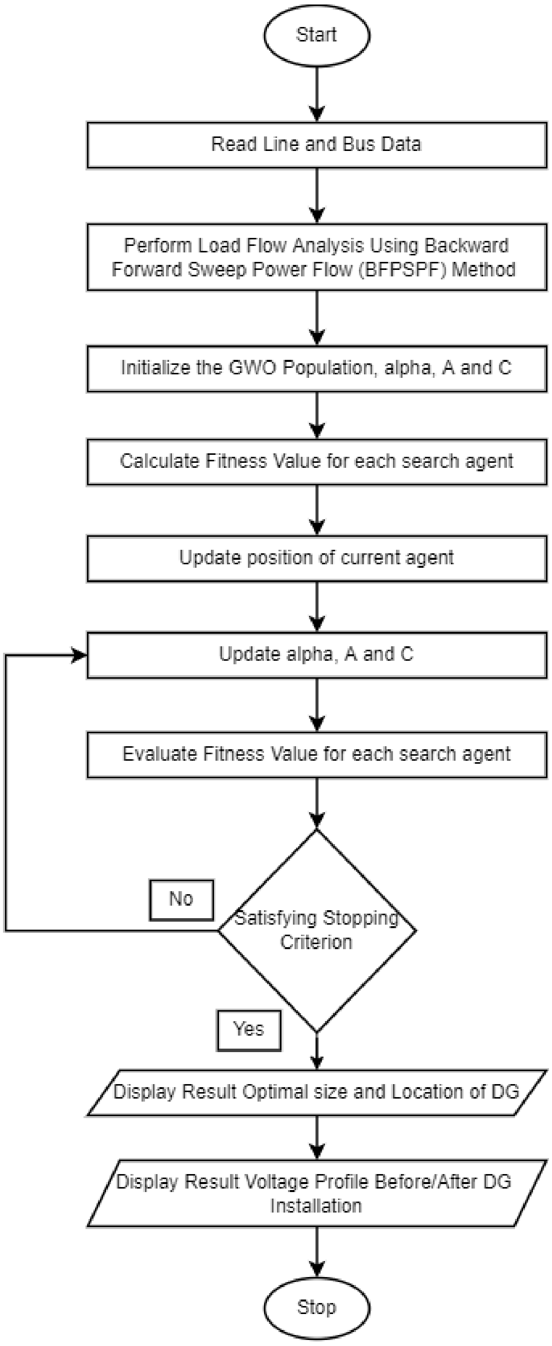

Figure 3.8 Flowchart for Case 3

The load flow in the radial distribution network with DG are performed with backward-forward power flow method and Grey Wolf Optimization (GWO) algorithm. The optimization method is used to find the optimal size and location of DG in the radial distribution network. The decision for the GWO algorithm is finish, when the value of alpha is met the satisfying stopping criterion.

3.4.7 Case 4: case study with considering network reconfiguration and with DG

Figure 3.9 depicts the flowchart for the optimization method with considering network reconfiguration.

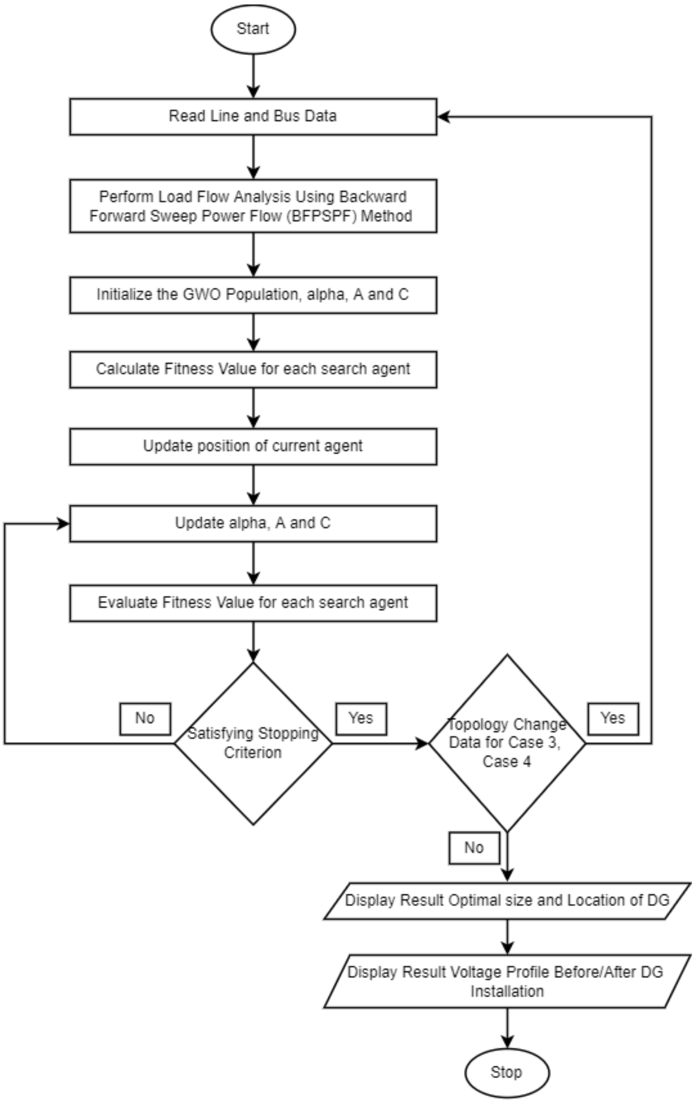

Figure 3.9 Flowchart for Case 4

GWO algorithm is used to find the optimal size and location of DG in the radial distribution network with DG considering network reconfiguration. A flowchart in this case is used two decision areas which is satisfying stopping criterion and topology change data for the GWO algorithm. Five tie-line data is being added to the IEEE 33-bus data from Table 3.1. Topology change data also know network reconfiguration is operate to increase voltage profile and reducing total power loss.

3.5 Objective Function

The evaluation will be done by using an objective function to minimise power loss. An objective function is used the equations for backward-forward power flow method and GWO algorithm.

$$P_{T,loss}(\mathrm{k}, \mathrm{k}+1) = \sum_{k=1}^{n} P_{loss}(k, k+1) \tag{3.10}$$

$$Q_{T,loss}(\mathrm{k}, \mathrm{k}+1) = \sum_{k=1}^{n} Q_{loss}(k, k+1) \tag{3.11}$$

where:

$P_{T,\ Loss}$ (k, k+1) – Total real power loss in the line section

$Q_{T,\ Loss}$ (k, k+1) – Total reactive power loss in the line section

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

This project was successfully completed. Backward-Forward Sweep Power Flow (BFSPF) method has successfully used in solving load flow problem. The proposed method is used to the IEEE 33-bus radial distribution network with and without considering network reconfiguration. The purpose of this study is to reduce power losses and increasing the voltage profile of the distribution network. GWO algorithm are used to find optimal size and location of the DG.

In this study is consider four different cases which two cases considering network reconfiguration without DG while the other two cases without considering network reconfiguration with DG. GWO algorithm are evaluate with the other optimization algorithm method which is PSO and MIOGA. Analysis of result is made base on result for all cases.

4.2 Result Test System

4.2.1 Case 1: Case Study without Considering Network Reconfiguration and without DG

Based on the graph in Figure 4.1 shows the voltage profile between each bus for Case 1.

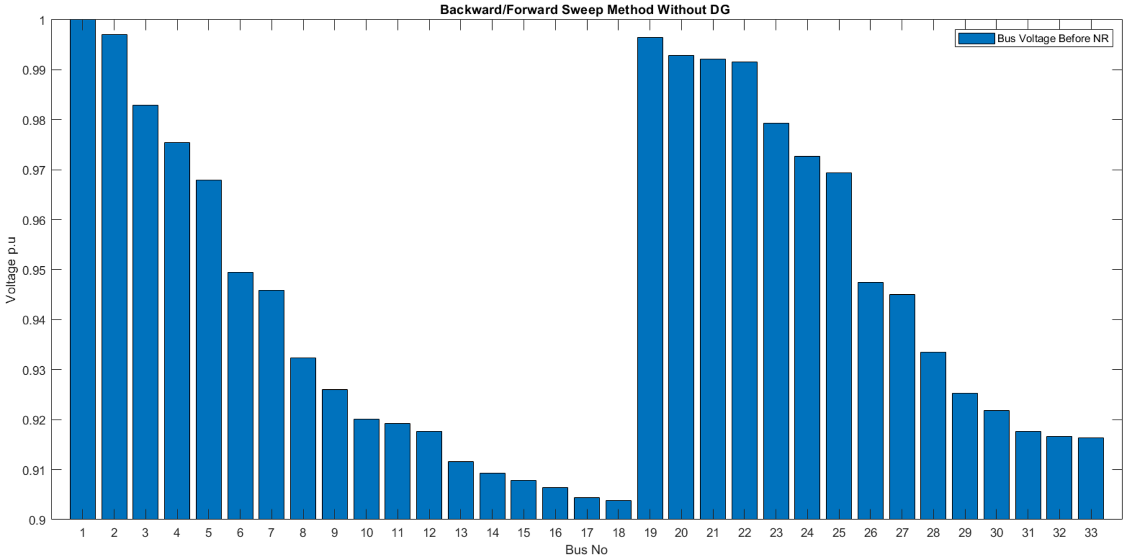

Figure 4.1 Graph Voltage Profile for Case1

Table 4.1 Voltage Magnitude for The Case 1

Bus No	**Voltage p.u**
1	1
2	0.997025
3	0.982893
4	0.975383
5	0.967957
6	0.949479
7	0.945954
8	0.932298
9	0.925966
10	0.920092
11	0.919223
12	0.917708
13	0.911532
14	0.909242
15	0.907815
16	0.906433
17	0.904385
18	0.903772

19	0.996497
20	0.992919
21	0.992215
22	0.991577
23	0.979307
24	0.972636
25	0.96931
26	0.947549
27	0.944985
28	0.933543
29	0.925324
30	0.921765
31	0.917603
32	0.916688
33	0.916404

Table 4.2 Performance of The Method for Case 1

Parameter	Value
Active Power Loss (kW)	211
Reactive Power Loss (kVar)	143.03
Vmin/Bus	0.9038/18

The voltage magnitude, total active and reactive power losses for the 33-bus system are calculated using the backward-forward sweep power flow method. Table 4.1 shows the voltage magnitude at all the difference buses. The total active and reactive power losses are shows at Table 4.2. Total reactive power loss is 211kW and the reactive power loss is 143.03kVar. The critical voltage magnitude of proposed method is 0.9038 p.u which is located at bus number 18. The method of backward-forward sweep power flow without considering network reconfiguration is presented in radial distribution networks. The backward and forward propagation iterative equation carries the distribution power flow. The power of each branch has been determined by using backward propagation. In forward propagation, the voltage magnitudes at each node are calculated. The IEEE 33-bus test system results have been tabulated. The proposed method of load flow is found to be ideal for quick convergence features and radial structure.

4.2.2 Case 2: Case Study with Considering Network Reconfiguration and without DG

The voltage profile between each difference bus can be seen in the Figure 4.2 for the Case 2.

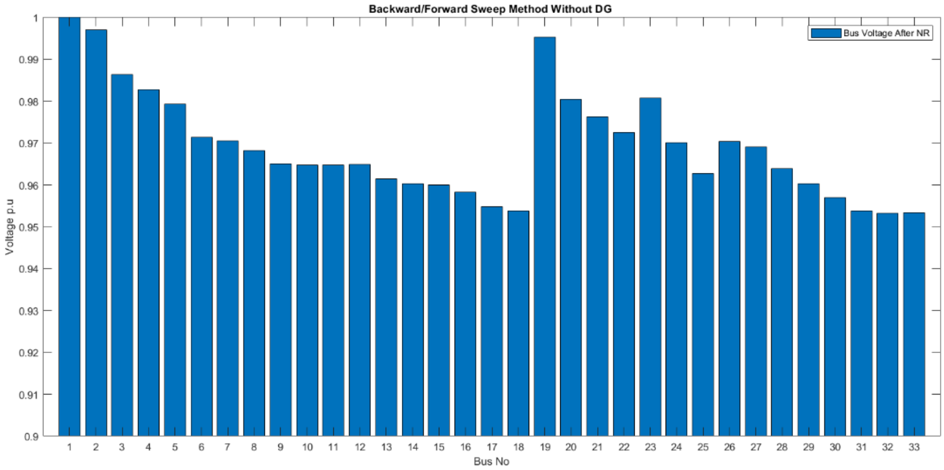

Figure 4.2 Graph Voltage Profile for The Case 2

Table 4.3 Voltage Magnitude for Case 2

Bus No	Voltage p.u
1	1
2	0.997092
3	0.986331
4	0.98271
5	0.979328
6	0.971423
7	0.970502
8	0.968249
9	0.965089

10	0.964719
11	0.96473
12	0.964884
13	0.961518
14	0.960324
15	0.959984
16	0.95825
17	0.954848
18	0.953813
19	0.9953
20	0.980424
21	0.976261
22	0.972511
23	0.980833
24	0.970109
25	0.962764
26	0.970402
27	0.969107
28	0.963835
29	0.960255
30	0.957014
31	0.953797
32	0.953219
33	0.953402

Table 4.4 Performance of The Method for Case 2

Parameter	**Value**
Active Power Loss (kW)	123.37
Reactive Power Loss (kVar)	88.34
Vmin/Bus	0.9532/32

Using backward-forward sweep power flow method, the voltage magnitude, total active and reactive power losses for the 33-bus system are calculated. Table 4.3 shows the voltage magnitude at each difference bus. Table 4.4 shows the total active and reactive power losses. Total reactive power loss is 123.37kW and the reactive power loss is 88.34kVar. The critical voltage magnitude of proposed method is located at bus number 32 which is 0.9532 p.u. In radial distribution networks, the method of backward-forward sweep power flow with network reconfiguration are presented. The distribution power flow is performed by the iterative backward and forward propagation equation. Backward propagation is being used to determine the power of each branch. The voltage magnitudes at each node are calculated in forward propagation. The iterations have a rapid potential for convergence. The IEEE 33-bus with added five tie-line switches for test system results have been tabulated. The proposed load flow method is found to be ideal for fast convergence features and radial structure.

4.2.3 Case 3: Case Study without Considering Network Reconfiguration and with DG

Figure 4.3 represents the voltage profile between each difference bus for the Case 3.

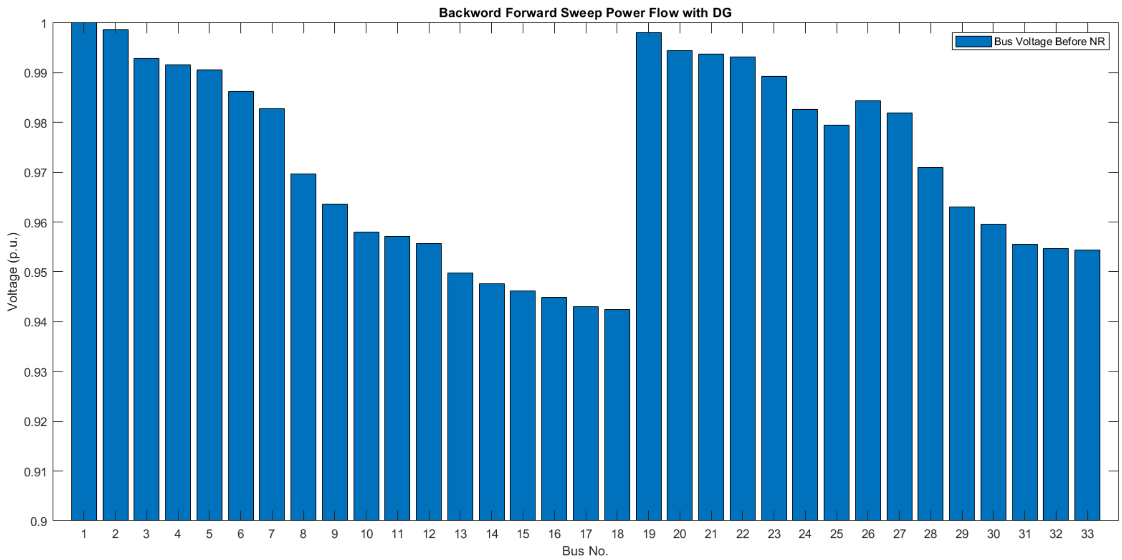

Figure 4.3 Graph Voltage Profile for Case 3

Table 4.5 Voltage Magnitude for Case 3

Bus No	Voltage p.u
1	0.998591193
2	0.992846254
3	0.991551125
4	0.990606018
5	0.98622831
6	0.982844623
7	0.969734594
8	0.96365741
9	0.958020842
10	0.957187232
11	0.955733757
12	0.94980947
13	0.947612858
14	0.946244331
15	0.944918853
16	0.942954644
17	0.942366438
18	0.998063661
19	0.994491707
20	0.993788315
21	0.993151902
22	0.98929715
23	0.982694235
24	0.979403362
25	0.984374809
26	0.981911971
27	0.970922792
28	0.963028595
29	0.959611614

30	0.955615475
31	0.954736369
32	0.954463981
33	0.998591193

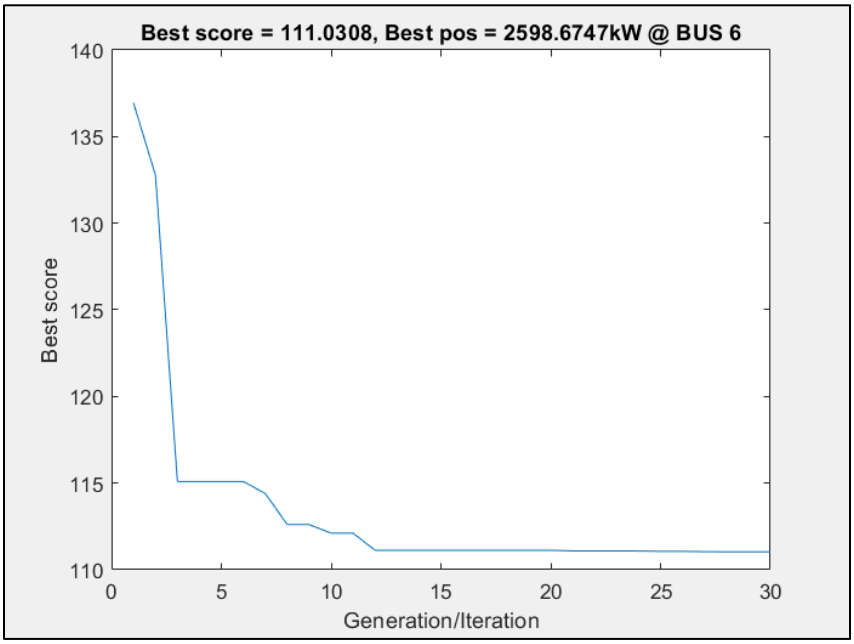

Figure 4.4 Convergence Curve of The GWO Algorithm for Case 3

Figure 4.4 shows the best score computed by GWO algorithm in MATLAB. The optimization method is operated by installing a 2.59 MW DG at location bus number 6. Table 4.6 shows the results are obtained from MATLAB simulation.

Table 4.6 Performance of The Method for Case 3

Parameter	**Value**
DG size (MW) / Bus No	2.58 / 6
Active Power Loss (kW)	111.03
Reactive Power Loss (kVar)	81.67
Vmin/Bus	0.9422/18
Time Simulation(s)	3.3479

The voltage magnitude, total active and reactive power losses for the 33-bus system are calculated using the GWO algorithm. Table 4.5 shows the voltage magnitude at each difference bus. The DG size and location, total active and reactive power losses are shows at Table 4.6. Total reactive power loss is 111.03kW and the reactive power loss is 81.67kVar. The critical voltage magnitude of proposed method is 0.9422 p.u which is located at bus number 18. By using GWO algorithm, time simulation is 3.3479 second. The method of GWO algorithm is presented in radial distribution networks. GWO algorithm is inspired by the hunting phenomenon of grey wolves in nature. The IEEE 33-bus test system results have been tabulated. The proposed method of load flow was found to be ideal for quick convergence features and radial structure.

4.2.4 Case 4: Case Study with Considering Network Reconfiguration and with DG

Figure 4.5 depicts impact of network reconfiguration and DG on voltage profile and all buses.

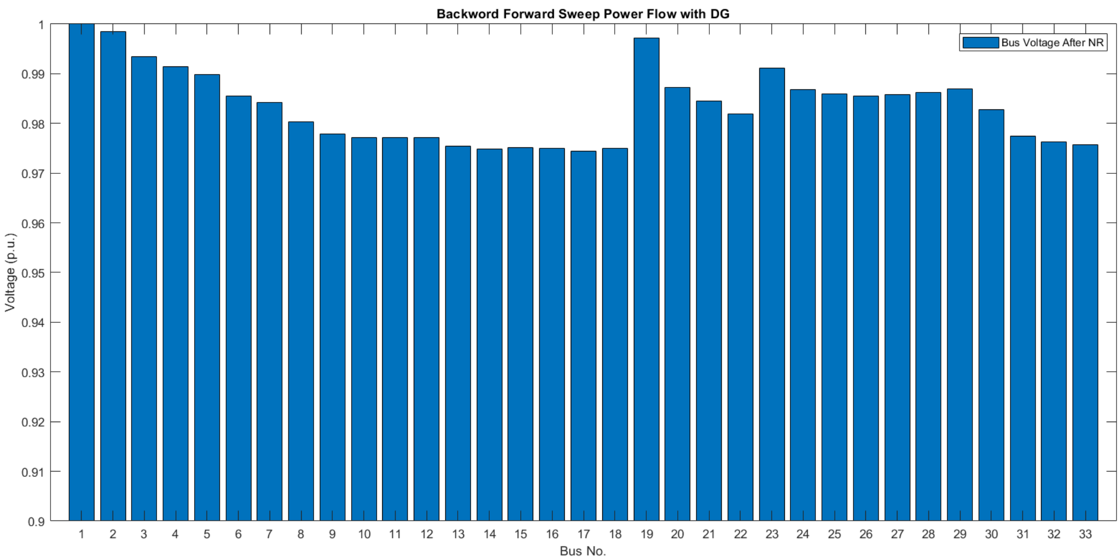

Figure 4.5 Graph Voltage Profile for Case 4

Table 4.7 Voltage Magnitude for Case 4

Bus No	Voltage p.u
1	1
2	0.998449752
3	0.993426806
4	0.991446643
5	0.98977145
6	0.98545076
7	0.984249651
8	0.980279528
9	0.977919545
10	0.977205081
11	0.977155666
12	0.977192862
13	0.975387567
14	0.974802906
15	0.975083542
16	0.974938427
17	0.974462882
18	0.974988661
19	0.997205617
20	0.987305868
21	0.984548651
22	0.981891989
23	0.991164124
24	0.986883321
25	0.985931509
26	0.985528963
27	0.985770451
28	0.986196949
29	0.986953146

30	0.982751379
31	0.977504965
32	0.976259352
33	0.975662732

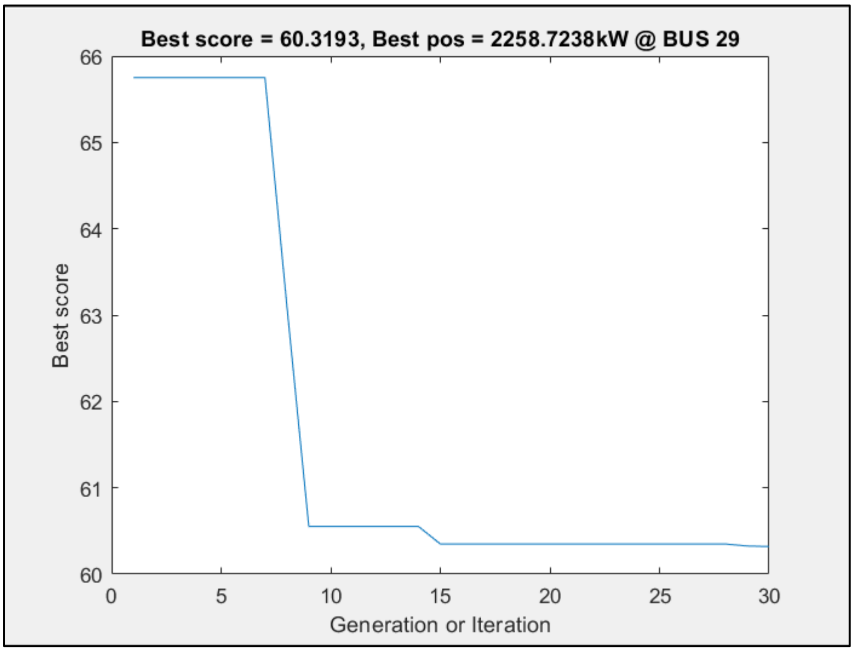

Figure 4.6 Convergence Curve of The GWO Algorithm for Case 4

Figure 4.6 shows the best score computed by GWO algorithm in MATLAB. The optimization method is operated by installing a 2.26 MW DG at location bus number 29. Table 4.8 shows the results are obtained from MATLAB simulation.

Table 4.8 Voltage Magnitude for Case 4

Parameter	Value
DG size (MW) / Bus No	2.26 / 29
Active Power Loss (kW)	60.32
Reactive Power Loss (kVar)	46.25
Vmin/Bus	0.9761/32
Time Simulation(s)	3.3649

The GWO algorithm with network reconfiguration is being used to calculate the voltage magnitude, total active and reactive power losses for the 33-bus system. The magnitude of the voltage at each difference bus is shown in Table 4.7. The DG size and location, total active and reactive power losses are shows at Table 4.8. Total reactive power loss is 60.32 kW and the reactive power loss is 46.25kVar. The critical voltage magnitude of proposed method is 0.9761 p.u which is located at bus number 32. By using GWO algorithm, time simulation is 3.3649 second. In radial distribution networks, the GWO algorithm method with network reconfiguration are presented. GWO algorithm is inspired by the hunting phenomenon of grey wolves in nature. The IEEE 33-bus with added five tie-line switches for test system results have been tabulated. The proposed load flow method is found to be ideal for fast convergence features and radial structure.

4.3 Analysis Data

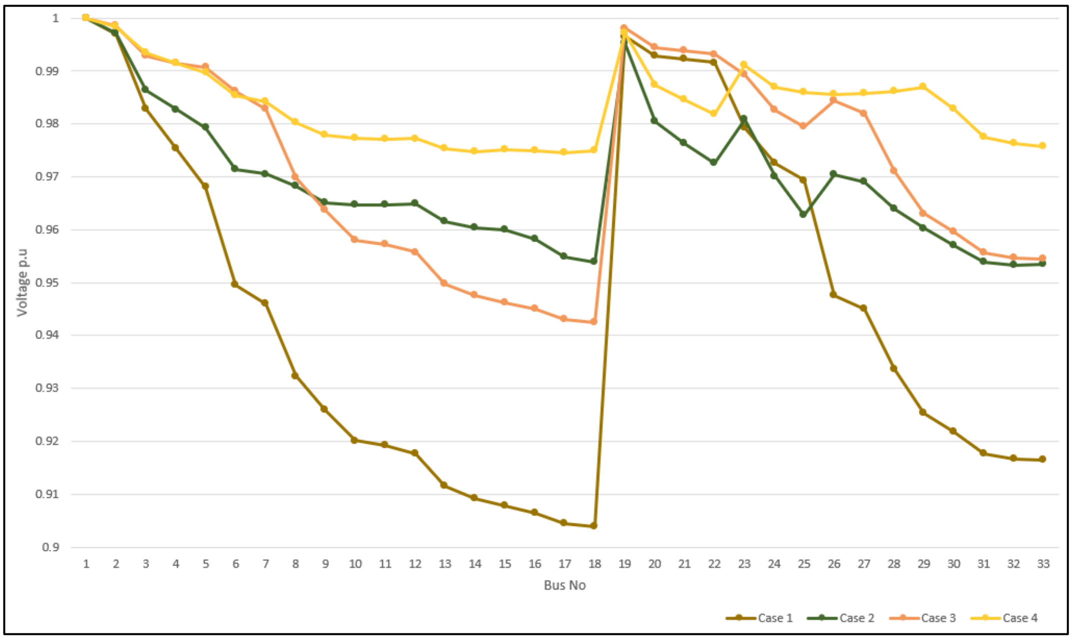

Figure 4.7 Improvement in Bus Voltage Profile in IEEE 33-Bus System

Figure 4.7 shows the voltage profile with and without considering network reconfiguration with DG and without DG, respectively, has been recorded. All the shapes of the voltage profiles are the same except the value of the voltage magnitude in the variety of cases. In the case 1, the value of the critical voltage is lower, which is 0.9038 p.u at the without considering network reconfiguration compared to the case 3 at the without considering network reconfiguration with placing the DG location. In case 4, the voltage magnitude increases after considering network reconfiguration and DG placement with optimal size and location to 0.9763 p.u compared to case 2, which only considers network reconfiguration without DG. Next, the network reconfiguration and DG placement have affected the improvement voltage profile.

Table 4.9 Summary Result for All Cases

Parameter	**Case 1**	**Case 2**	**Case 3**	**Case 4**
Active Power Loss (kW)	211	123.37	111.03	60.31
% Active Power Loss Reduction	-	41.53	47.38	71.41
Reactive Power Loss (kVar)	143.03	88.34	81.67	46.25
DG size (MW) / Bus No	-	-	2.58 / 6	2.26 / 29
Vmin/Bus	0.9038/18	0.9532/32	0.9422/18	0.9761/32

Table 4.9, shows the comparison of the optimization result for difference cases. The process of moving loads from a heavy-loaded feeder to a light-loaded feeder by changing the distribution system's topological structure is more affective in case 2 and 4 compare to without considering network reconfiguration in case 1 and 3. However, with optimal size and location of the DG into RDN are impacted to the minimising total power loss as shown in Case 4 compared to the other cases. It is because the DG only provides the active power losses in RDN. According to the findings, the optimal position and size of DG units are changed as a response of network reconfiguration. At the Case 3 are reduce of the size of DG which is from 2.58 MW to 2.26MW after network reconfiguration in Case 4. There is reduce around 12.40% after network reconfiguration. The study indicates that network reconfiguration and optimal size and placement DG are given the higher impact. According to the Case 4, the result is obtained on reducing the total power losses to 60.31 kW and critical voltage profile increase to 0.9761 p.u which located at bus number 32.

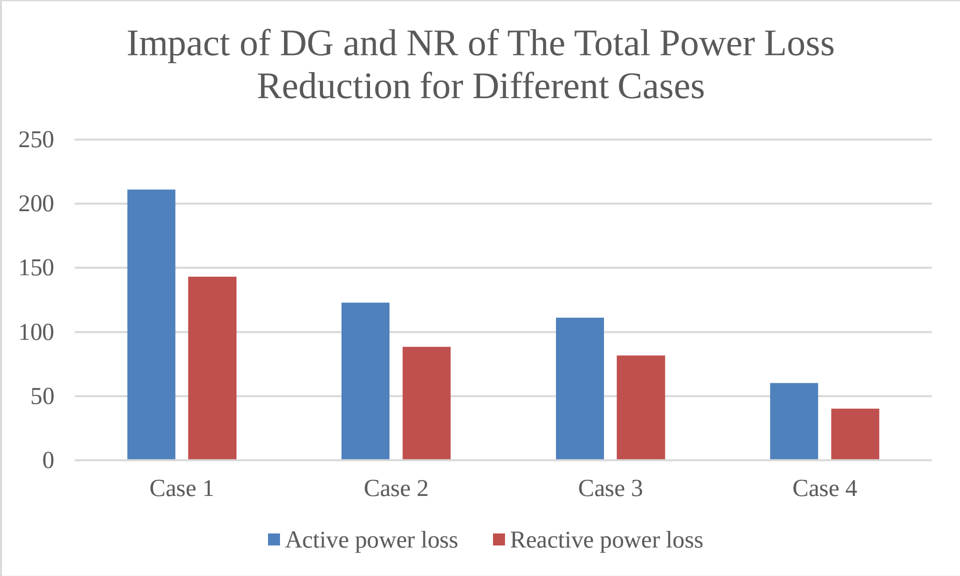

Figure 4.8 Comparison of Power Losses for Different Condition

Table 4.10 Impact of DG and Network Reconfiguration for Difference Cases.

Parameter	Case 1	Case 2	Case 3	Case 4
Active Power Loss (kW)	211	123.37	111.03	60.31
% Active Power Loss Reduction	-	41.53	47.38	71.41
Reactive Power Loss (kVar)	143.03	88.34	81.67	46.25
% Reactive Power Loss Reduction	-	38.24	7.55	43.40

Network reconfiguration and DG placement are affected into the active power losses and reactive power losses. Case 2 is operated in the network reconfiguration are resulted the total active power loss is reducing to 123.37 kW with 41.53 % power loss reduction. The DG are installed for the Case 4. There are resulted to the total active power loss is reducing to 60.31kW with 71.41% power loss reduction. Reactive power loss is reduced from 143.03kVar for the Case 1 to 46.25kVar for the Case 4 with percentage of reactive power loss reduction is 43.40%.

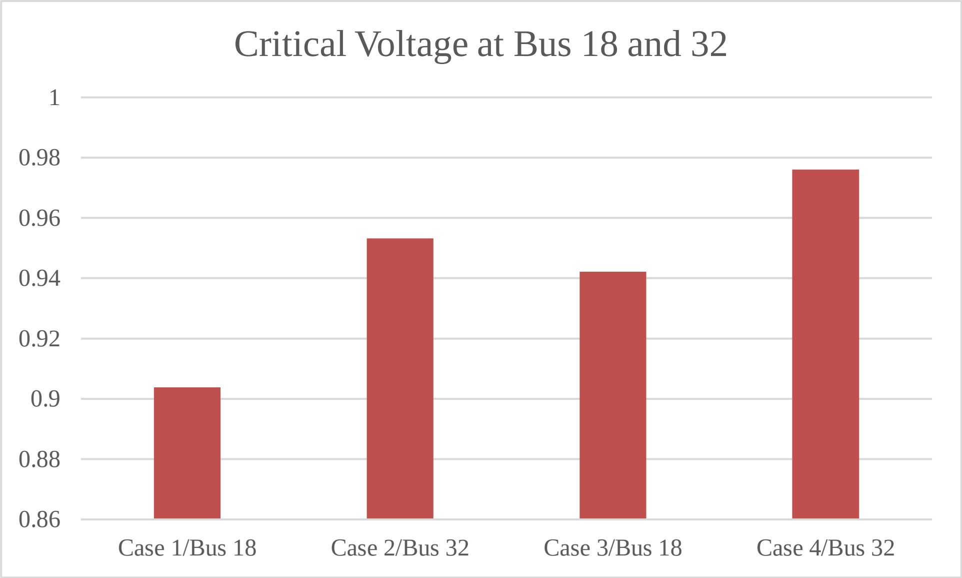

Figure 4.9 Comparison of Critical Voltage for Different Case and Bus

Table 4.11 Summary Result of The Difference Case for Critical Voltage Magnitude

Cases	**Critical Voltage p.u (Bus)**
Case 1	0.9038 (18)
Case 2	0.9532 (32)
Case 3	0.9422 (18)
Case 4	0.9761 (32)

Figure 4.9 shows the graph of the comparison of the critical voltage for difference cases and bus. The result of the comparison is tabulated in Table 4.11. Network reconfiguration and DG placement are affected for the critical voltage profile with location number of bus. Case 1 is located bus number 18 which is 0.9038 p.u. Case 2 are 5.16% increment which is 0.9532 located at bus number 32. Case 3 is a 4.24% increment which is 0.9422 located at bus number 18. Case 4 is the higher increment with 7.99% which is 0.9761 at located bus number 32.

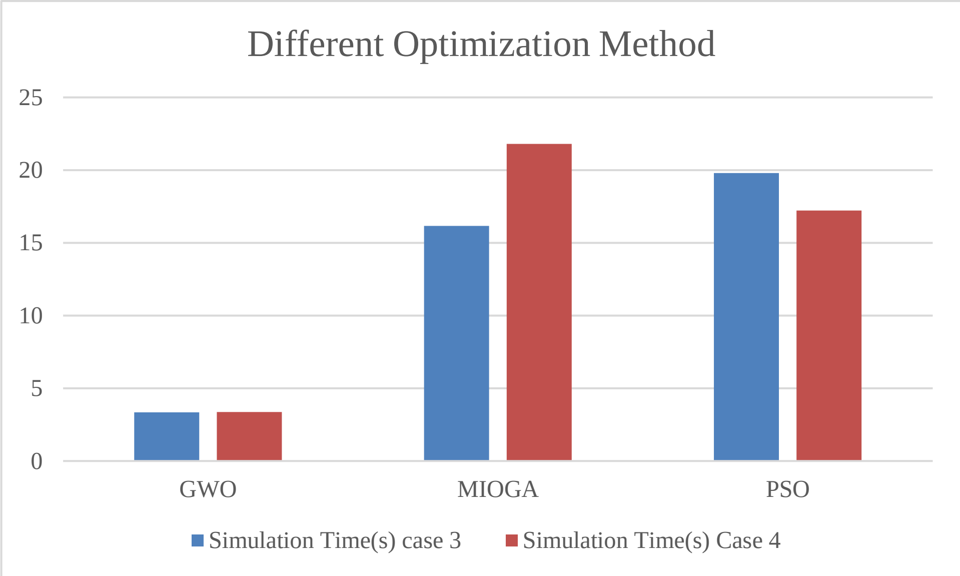

Figure 4.10 Comparison Different Optimization Method

Table 4.12 Summary Result for The Difference Optimization Method

Method	**Parameter**	**Case 3**	**Case 4**
GWO	Active Power Loss (kW)	111.03	60.32
	% Active Power Loss Reduction	47.38	71.41
	Reactive Power Loss (kVar)	81.67	46.25
	DG size (MW) / Bus No	2.58 / 6	2.26 / 29
	Vmin/Bus	0.9422/18	0.9761/32
	Simulation time(s)	3.3479	3.3649
MIOGA	Active Power Loss (kW)	111.03	60.31
	% Active Power Loss Reduction	47.38	71.42
	Reactive Power Loss (kVar)	81.68	46.28
	DG size (MW) / Bus No	2.59 / 6	2.27 / 29
	Vmin/Bus	0.9424/18	0.9763/32
	Simulation time(s)	16.1677	21.8012
PSO	Active Power Loss (kW)	111.03	60.32
	% Active Power Loss Reduction	47.38	71.42

	Reactive Power Loss (kVar)	81.68	46.28
	DG size (MW) / Bus No	2.59 / 6	2.27 / 29
	Vmin/Bus	0.9038/18	0.9763/32
	Simulation time(s)	19.8080	17.2114

Figure 4.10 show the comparison the performance of GWO, MIOGA and PSO algorithm. The MATLAB simulation result are tabulated in Table 4.12. GWO algorithm are compare for the Case 3 and Case 4. According to the result of difference optimization method is the almost similar value except for the simulation time. This comparison is focus on the simulation time for each optimization method. Simulation time for Case 3 is used GWO algorithm is 3.3479 second compare to the PSO and MIOGA which is 19.8080 second and 16.1677 second respectively. GWO algorithm are simulated for the Case 4 which are time taken is 3.3649 second compare to the PSO and MIOGA which is 21.8012 second and 17.2114 second respectively. From that, the GWO algorithm is more effectiveness compare to the MIOGA and PSO method.

CHAPTER 5

CONCLUSION

5.1 Conclusion

Distribution system design and planning is having a major fundamental change as a result of activities of the energy industry, regulatory reforms, and advancements in DG technology. In light of these advances, this study focuses on distribution system planning. After that, there is a quick overview of distribution system planning, network reconfiguration and DG penetration.

The obtained result in this study for a method of Grey Wolf Optimization (GWO) embedded Backward Forward Sweep Power Flow (BFSPF). This method is established for optimal location and size of DG to help for reducing power losses and improving voltage profile with considering network reconfiguration in radial distribution system network planning. IEEE 33-bus network and tie-line switches are used to accomplish the simulation for the proposed method.

GWO algorithm is used for optimal location and size of DG. Network reconfiguration with DG placement is affected into the total power loss minimization and increasing voltage profile. In terms of active power loss minimization is reduce to the 71.42% power loss reduction. Improvement of the voltage profile is obtained which is 7.99%. The performance of Grey Wolf Optimization (GWO), Mix Integer Optimization Genetic Algorithm (MIOGA) and Particle Swarm Optimization (PSO) are obtained. Simulation time for the GWO algorithm is compared to the MIOGA and PSO method. The computational results showed that performance of the GWO algorithm is more effective compare to the MIOGA and PSO in term of the simulation time taken.

As a result, the study requirements were achieved and the network reconfiguration are implemented of the BFSPF method and GWO algorithm. There is demonstrated to be an effective method for optimising the location and size of DG in different power networks with the achieve of reducing both real and reactive power losses while voltage profiles are increase.

5.2 Recommendation

Future investigations can be conducted based on the project's success in this research. The following are some ideas:

I. Planning Engineers should investigate the negative consequences of DG that can be mitigated by proper DG allocation.

II. Simulating in approach technique required a long time to iterate, thus further effort must be done to reduce this time.

III. More work may be done in the future to make AI optimization algorithms more flexible to the volatility of renewable energy sources.

IV. Other power system issues, such as worries about stability, might be considered to improve the multi-objective function.

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APPENDIX A

Table 1: Network data of the test system

Br. No	Rc. Nd.	Sn. Nd.	Br. Prm. r(ohm)	x(ohm)	Sn. Node PL(kW)	QL(kvar)	|V|**2
1	0	1	0.0922	0.0470	100.00	60.00	0.9927
2	1	2	0.4930	0.2511	90.00	40.00	0.9574
3	2	3	0.3660	0.1864	120.00	80.00	0.9374
4	3	4	0.3811	0.1941	60.00	30.00	0.9176
5	4	5	0.8190	0.7070	60.00	20.00	0.8707
6	5	6	0.1872	0.6188	200.00	100.00	0.8641
7	6	7	0.7114	0.2351	200.00	100.00	0.8550
8	7	8	1.0300	0.7400	60.00	20.00	0.8432
9	8	9	1.0440	0.7400	60.00	20.00	0.8324
10	9	10	0.1966	0.0650	45.00	30.00	0.8308
11	10	11	0.3744	0.1238	60.00	35.00	0.8280
12	11	12	1.4680	1.1550	60.00	35.00	0.8167
13	12	13	0.5416	0.7129	120.00	80.00	0.8125
14	13	14	0.5910	0.5260	60.00	10.00	0.8099
15	14	15	0.7463	0.5450	60.00	20.00	0.8074
16	15	16	1.2890	1.7210	60.00	20.00	0.8037
17	16	17	0.7320	0.5740	90.00	40.00	0.8026

Br. No	Rc. Nd.	Sn. Nd.	Br. Prm. r(ohm)	x(ohm)	Sn. Node PL(kW)	QL(kvar)	|V|**2
18	1	18	0.1640	0.1565	90.00	40.00	0.9916
19	18	19	1.5042	1.3554	90.00	40.00	0.9845
20	19	20	0.4095	0.4784	90.00	40.00	0.9831
21	20	21	0.7089	0.9373	90.00	40.00	0.9818
22	2	22	0.4512	0.3083	90.00	50.00	0.9504
23	22	23	0.8980	0.7091	420.00	200.00	0.9373
24	23	24	0.8960	0.7011	420.00	200.00	0.9309
25	5	25	0.2030	0.1034	60.00	25.00	0.8643
26	25	26	0.2842	0.1447	60.00	25.00	0.8557
27	26	27	1.0590	0.9337	60.00	20.00	0.8201
28	27	28	0.8042	0.7006	120.00	70.00	0.7945
29	28	29	0.5075	0.2585	200.00	600.00	0.7816
30	29	30	0.9744	0.9630	150.00	70.00	0.7739
31	30	31	0.3105	0.3619	210.00	100.00	0.7723
32	31	32	0.3410	0.5302	60.00	40.00	0.7717

------ TIE LINES ------

Br. No	Rc. Nd.	Sn. Nd.	Br. Prm. r(ohm)	x(ohm)
33	7	20	2.0000	2.0000
34	8	14	2.0000	2.0000
35	11	21	2.0000	2.0000
36	17	32	0.5000	0.5000
37	24	28	0.5000	0.5000