OPTIMAL PLANNING OF DISTRIBUTED GENERATION CONSIDERING TIME VARYING LOAD

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Optimal Planning of Distributed Generation Considering Time Varying Load

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ABSTRAK

Penjanaan Teragih (DG) berasaskan tenaga boleh diperbaharui adalah penting untuk infrastruktur tenaga jangka panjang kerana ia tidak mencemarkan dan tidak terhad. Ketidakpastian yang berkaitan dengan sumber DG boleh mengakibatkan isu ekonomi dan teknologi tertentu yang memerlukan pemeriksaan menyeluruh untuk memudahkan penyepaduan mereka ke dalam sistem pembahagian elektrik (DS). Tesis ini mengkaji pengaruh pemodelan beban berubah-ubah masa ke atas perancangan DG berasaskan fotovoltaik (PV). Tujuan tesis ini adalah untuk membentangkan kaedah gabungan yang berkesan berdasarkan Aliran Kuasa Sapuan Ke Depan (BFSPF) dan Pengoptimuman Integer Campuran oleh Algoritma Genetik (MIOGA) bagi menyelesaikan masalah rangkaian dengan kehadiran DG dengan tujuan membangunkan aliran kuasa untuk sistem pengagihan jejari dengan mempertimbangkan beban yang berubah-ubah masa, mengoptimumkan dudukan dan saiz DG dalam rangkaian pengedaran jejarian untuk pengurangan kerugian dan peningkatan voltan dan membuat perbandingan rangkaian pengedaran jejarian dengan DG tunggal dan berbilang dengan mengambil kira keadaan beban yang berbeza-beza masa. . Dalam rangkaian pengedaran jejari, MIOGA digunakan untuk mencari nilai terbaik untuk saiz DG secara serentak. Kesan teknik berdasarkan algoritma MIOGA untuk mencari konfigurasi minimum pada kehilangan kuasa sebenar rangkaian dan profil voltan diperiksa. Prestasi dan keberkesanan teknik yang disyorkan ditunjukkan menggunakan sistem ujian bas IEEE 33. Dengan pemasangan PVDG, hasil simulasi menunjukkan pengurangan kehilangan kuasa keseluruhan dan peningkatan dalam magnitud voltan untuk rangkaian. Pemasangan PVDG boleh meminimumkan kehilangan kuasa sehingga 33%, menurut penemuan. Selain daripada mengurangkan kerugian, memasang DG dengan MIOGA juga membantu meningkatkan profil voltan rangkaian pengedaran jejari. Mengikut keputusan, algoritma MIOGA adalah yang terbaik untuk mengurangkan kehilangan kuasa sebenar dan meningkatkan profil voltan, dan ia mungkin digunakan untuk membuat keputusan perancangan rangkaian pengedaran.

ABSTRACT

Renewable energy-based Distributed Generation (DG) resources are critical for long-term energy infrastructure since they are non-polluting and limitless. The uncertainties connected with DG resources may result in specific economic and technological issues that need a thorough examination to simplify their integration into the Distribution System (DS). This thesis examines the influence of time-varying load modeling on photovoltaic (PV)-based DG planning. The purpose of this thesis is to present an effective combination method based on Backward Forward Sweep Power Flow (BFSPF) and Mix Integer Optimization by Genetic Algorithm (MIOGA) to solve the network problem in the presence of DG with the purpose of developing power flow for radial distribution system by considering time-varying load, optimize the sitting and sizing of the DG in the radial distribution network for the loss minimization and voltage improvement and make comparison radial distribution network with single and multi-DG by considering time varying load condition. In a radial distribution network, MIOGA is utilized to find the best value for DG size concurrently. The effect of a technique based on the MIOGA algorithm to find the minimal configuration on network actual power losses and voltage profiles is examined. The performance and effectiveness of the recommended technique are demonstrated using the IEEE 33- bus test system. With the installation of PVDG, the simulation results show a reduction in overall power loss and an improvement in voltage magnitudes for the network. PVDG installation can minimize power loss by up to 33%, according to the findings. Aside from lowering losses, installing DG with MIOGA also helps to enhance the voltage profile of the radial distribution network. According to the results, the MIOGA algorithm is best at reducing actual power loss and improving voltage profiles, and it may be utilized to make distribution network planning decisions.

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LIST OF SYMBOLS

V_o	Voltage magnitude at sending end
V_i	Voltage magnitude at sending end of line i
V_n	Voltage magnitude at receiving end
P_{PV}	Photovoltaics’ output power
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
$PT_{loss}(i, i+1)$	Total Real Power Loss in the line section
$QT_{loss}(i, i+1)$	Total Reactive Power Loss in the line section

LIST OF ABBREVIATIONS

ANN	Artificial Neural Network
CHP	Combined Heat and Power
DG	Distributed Generation
GA	Genetic Algorithm
HAS	Harmony Search Algorithm
HAWT	Horizontal Axis Wind Turbine
VAWT	Vertical Axis Wind Turbine
HV	High Voltage
IGBT	Insulated Gate Bipolar Transistor
IGA	Immune-Genetic Algorithm
IMO	Multi Objective Index
BFSPF	Backward Forward Sweep Power Flow
NOX	Nitrogen Oxide
OPF	Optimal Power Flow
PDF	Probability Density Function
ACO	Ant Colony Optimization
SA	Simulated Annealing
MA	Mimetic Algorithm
DE	Differential Evolution
PSO	Particle Swarm Optimization
MIOGA	Mix Integer Optimization Genetic Algorithm
PWM	Pulse Width Modulation
PV	Photovoltaic

PVDG	Photovoltaic Distributed Generation
GA	Genetic Algorithm
RES	Renewable Energy Resources
IEEE	Institute of Electrical and Electronics Engineers
RDN	Radial Distribution Network
TNB	Tenaga Nasional Berhad
MW	Megawatt
kW	Kilowatt
kVar	Kilovolt-Ampere Reactive
MVA	Megavolt Ampere
p.u	Per unit

CHAPTER 1

INTRODUCTION

1.1 Background

Small generators powered by steam engines were used to generate electricity at first. It was distributed and used in a small region close to where it was created. Because of the fast increase in demand and power losses, the power system has become increasingly complex a contemporary power system consists of long linked transmission lines and huge centralised power plants. Centralized power generation has primarily contributed to the availability of electric power to the public throughout the previous few decades. The main advantages of centralised power generation are its great efficiency and dependability. However, there are several drawbacks to its operation that have diverted the world's focus away from centralised power generation. One major downside is that, because to the size of these power facilities, they need significant investment and running expenditures. Second, transmission networks throughout the world are nearing their capacity, making it impossible for them to meet additional electricity demand. Furthermore, increased consumer awareness and current societal proclivities toward "green power" technologies have sparked interest in cleaner, more sustainable power generation. As a result, the world's attention has switched to tiny, decentralised power generation units located near client locations. This is sometimes referred to as Distributed Generation (DG)[1].

DG is made up of both conventional and non-conventional energy resources with capacities ranging from a few kW to several MW. They can operate as a stand-alone power plant or as part of a larger grid, supplying electricity to many clients in remote locations. Conventional DGs, which mainly comprise fuel cell and gas turbine-based power plants, rely on fossil fuel to create electric power.

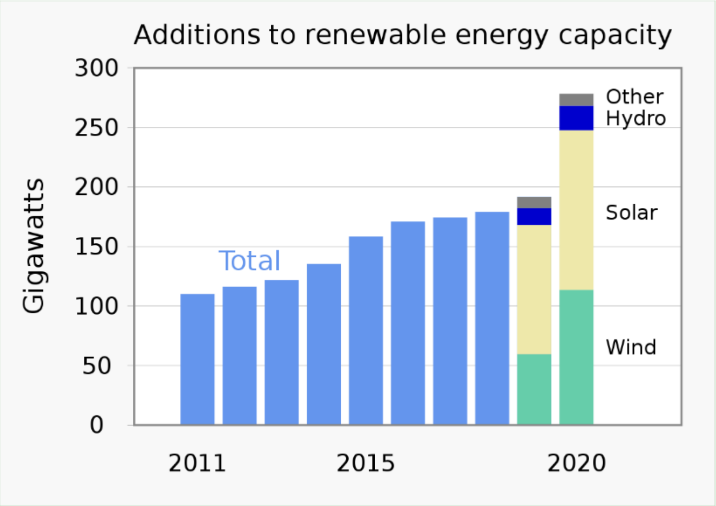

Figure 1.1 Global additions of renewable energy capacity

When compared to conventional energy sources, which are restricted and only exist several geographical areas, renewable energy resources are free and available in many countries. Power generation from renewable energy resources is developing at a rapid pace due to considerations such as secure and reliable energy, climate change mitigation, unlimited availability, and economical benefits. Figure 1.1[2] depicts the global renewable energy development from 2011 to 2020, demonstrating that these energy resources have grown at a reasonable rate.

1.2 Problem Statement

From the perspective of the service provider, the introduction of renewable energy-based DG systems like as solar and wind in the distribution system may result in various economic, technical, and environmental benefits. These DG units are often situated near the customer's premises. However, the increased penetration of these resources, along with demand changes, has created several issues for distribution networks, including power fluctuations, high losses, voltage increases, and low voltage stability[3]. Most of the studies available in literature that deals with the integration of DG units in distribution system consider constant generation and load models in which demand, and generation is assumed to be fixed. However, in real scenario power generated from renewable energy resources and the electricity consumer demand is not constant. Therefore, to perform more realistic DG planning studies load variation are required.

A power system's electrical loads are often categorised as domestic, commercial, and industrial loads. Typically, these loads are linked to the power system at the secondary distribution level. Variations in frequency and voltage affect the changes in active power (P) and reactive power (Q) of the load. Because frequency variation is modest, the influence of voltage change on P and Q of the load is solely examined in load flow analysis.

Improper DG power allocation and sizing toward the distribution network causes power quality issues, increasing power losses, an unstable power system, and growing operating expenses. In this load model, the actual and reactive powers of the load are independent of the voltage variation. As a result, the employment of the constant-power load model has become very problematic, particularly in distribution systems where many of the system buses are not voltage-controlled. The constant impedance load model considers the variation in P and Q of the load with the voltage deviation, and it is discovered that when compared to the constant load model. To obtain more accurate representation of the load a time varying load modelling approach is considered in this report.

Because most of these generating units are based on renewable energy resources (RES), which are intermittent in nature, the output power provided by DG resources is often unpredictable and unreliable. The irregularity of DG unit output power results in large losses, power swings, and voltage stability concerns. Furthermore, it becomes difficult for the system operator to address all these difficulties while keeping the system operating. To estimate the output power produced by DG units based on intermittent energy supplies, the uncertainties associated with them must be modelled.

The smart grid concept is recent and foremost concern of modern advances in power industry, which is fostered by the short-term and long-term strategies of governments of developed counties. Smart grids are generally regarded as the solution to majority of modern grid problems.

1.3 Objective

The main goal of this research work is to develop methodologies for strategically planning and operating renewable DG units in distribution networks. This research work aims to check the effect of time varying load and probabilistic generation modelling on the performance of distribution system. The major objectives of the current research are highlighted as follows:

I To develop power flow for radial distribution system by considering time varying load.

II To optimize the sitting and sizing of the DG in radial distribution network for the loss minimization and voltage improvement.

III Comparison single and multi-DG by considering time varying load condition.

1.4 Scope of Work

A radial load flow study on standard 33-bus IEEE distribution network systems is part of the scope of work. For load flow solutions, an effective radial distribution system called Backward Forward Sweep Power Flow (BFSPF) Method will be used. It will also entail the development of an algorithm for optimal placement and sizing of the DG system in distribution networks using the Mix Integer Optimization by Genetic Algorithm (MIOGA) technique, which will consider time-varying loads and produce a technique for optimal placement and sizing of distribution generation in a radial distribution network for power loss minimization, voltage deviation, and voltage profile improvement in the system. In contrast to other approaches where only voltage profile improvement and power loss minimization were considered, the goal contribution in this research work will be the integration of MIOGA technique with Backward Forward Sweep Power Flow (BFSPF) Method of load flow solutions for the minimizations of active power loss and voltage deviation. Finally, comparing single and multi-DG by considering time-varying load conditions to determine whether single DG or multi-DG is the best solution for improving the radial distribution network is the best solution.

1.5 Thesis outline

The first chapter of this thesis provides an outline of the planned study as well as a quick description of how the entire research operates. The key issue statement and research objectives have been emphasised to provide some insight into the likely aim that will be attained at the conclusion of this study while adhering to the scope of work outlined in this chapter.

Chapter two is devoted to a broad literature study, in which other comparable research projects have been carried out in the past using various approaches in order to gain a better understanding of what has been done previously and possibly new results. In this chapter, it carries out the previous renewable energy used for DG system and the method that used for the investigation.

The major methodology and strategy used in this study to attain the main goal are described in Chapter 3. The logical processes involved in constructing the approach were outlined in this chapter. Here method that used in investigation is decided which is Backward Forward Sweep Power Flow (BFSPF) method combination with MIOGA.

Chapter four provides all the essential analysis, simulation, and constructed algorithm output results, as well as a discussion of the output results. Optimization result is shown in this chapter which contain the DG size and location, total power losses and the minimum voltage magnitude.

The conclusion, observations for future study areas, and some ideas on how to enhance the system are all included in Chapter 5. It can conclude that the result of the investigation meets with objective or not.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The primary concern of the power system utility is to provide dependable and secure electricity to its customers to fulfil the energy demand. Most nations throughout the world have centralised power systems, which use massive generators and lengthy transmission lines to generate and transport electricity. The best site for power generating is one where more electricity can be generated for the least amount of money. The generated electricity is subsequently sent to major load centres via transmission networks. The power is subsequently transferred to the customer's premises through distribution systems using appropriate voltage levels. Since the previous decade, power system deregulation has grown in importance in order to establish a competitive atmosphere. Large power producing units have always played an important role in centralised power systems[3]. However, it is envisaged that under a deregulated system, tiny producing units, also known as Distributed Generation (DG) units, will account for a major portion of electricity generation. The integration of DG with the electrical system provides various benefits to utilities and customers, including improved voltage profiles, reduced power losses, reactive power control, uninterrupted power supply, and increased efficiency. Aside from these benefits, there are a several technological issues that must be addressed before deploying DG on a wide scale. Figure 2.1 demonstrates the distinction between today's central utility and tomorrow's dispersed utility[3]. DG often relies on fluctuating renewable resources for electricity generation. The integration of these intermittent energy resources with the distribution system necessitates the use of planning approaches that consider the uncertainty associated with the increase of intermittent DG resources in the power system.

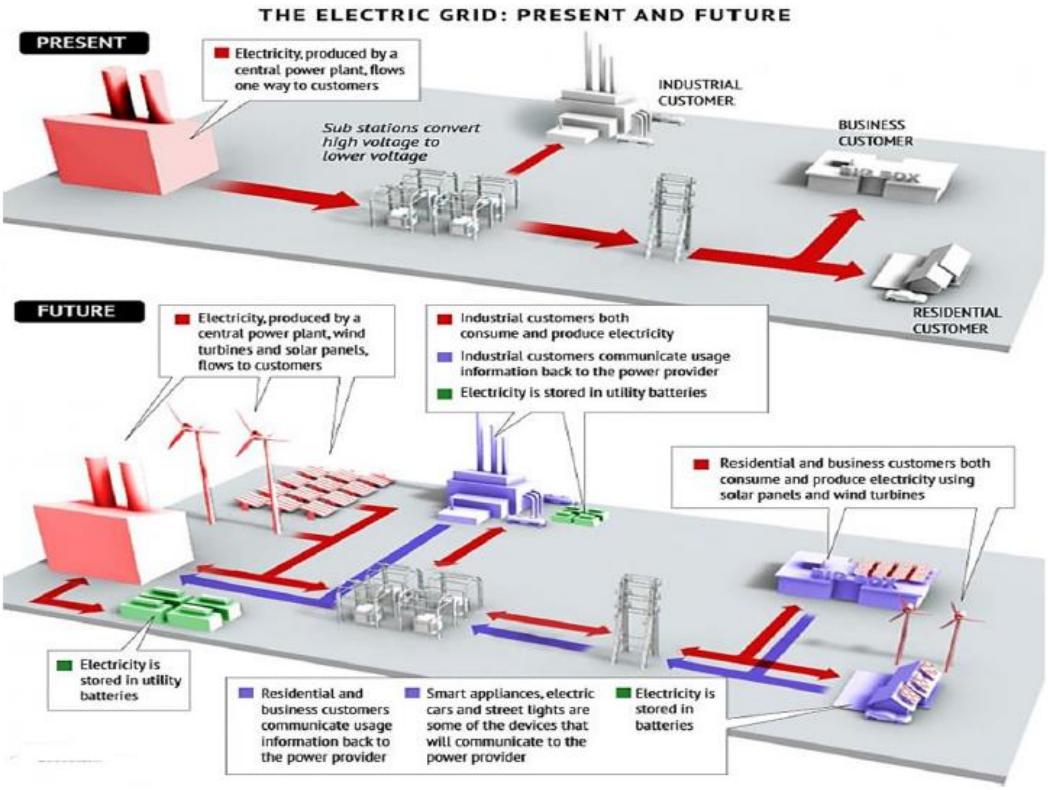

Figure 2.1 Present and Future Electric Grid [3]

Furthermore, growing DG deployment in distribution systems may provide operational issues. The system may provide operational issues like as bi-directional power flow and generation variance, which must be handled as well. The next parts discuss the DG ideas, its many technologies, as well as the advantages and influence on distribution networks. Furthermore, significant literature pertaining to the design and operational elements of DG integrated distribution systems is examined[3].

2.2 Essential concept of Distributed Generation

DG has gained a respectable percentage of global power generation during the last decade and a half for a variety of reasons. Electricity demand growth, advancements in distributed generation technologies, power system deregulation that allows for the integration of more generating units, environmental and financial constraints for transmission network expansion, and concerns about climate change have all combined to make renewable energy resource-based DG systems the best solution for meeting the growing demand for electricity[4].

It is difficult to discover in the literature a general definition of DG that is widely accepted by the power system community. Different nations define DG differently based on their technology, voltage level, size, connections in the distribution feeder, purpose of use, and kind of energy source (such as solar, wind, biomass, fuel cell, natural gas, and water) used to generate electricity. However, different definitions of DG are offered below:

Ackermann et al.[5] define distributed generation in terms of its connections with the distribution system rather than its capability for electricity generating. The term "DG" refers to "the source of electric power generation integrated directly with the distribution network or at individual customer premises." This definition is wide and does not impose any limitations on distributed generation capacity or technology.

The International Council on Large Electricity Systems (CIGRE) defines dispersed generation as "power producing units that are not centrally located and are typically connected with distribution systems with a rated capacity ranging from 50 MW to 100 MW"[6].

The IEEE defines distributed generation as "electric power generation by facilities that are authorised for integration in any power system and are significantly smaller in size than big centralised power plants"[7].

Chambers[8] describes DG as "the small power generators situated near the client premises for the economical and reliable functioning of the distribution system with a power generating capacity of 30 MW or less".

2.3 Distributed Generation

Currently, the majority of nations in the world generate electricity primarily through centralised power plants with high output capacity. These power generation units typically generate electricity using conventional energy resources such as hydro, nuclear, and fossil fuel. Electricity generated by these power facilities is often inexpensive and has a low per unit cost[9]. Centralized power plants are typically placed in remote locations from load centres, necessitating the use of extensive transmission lines to deliver power. The expense of installing these long transmission lines is enormous, and they have a severe impact on the environment. Furthermore, expanding transmission networks raise the likelihood of increased power losses, energy pilferage, and susceptibility to environmental dangers and terrorist threats[10].

In contrast, distributed generating technologies create tiny amounts of electricity (3 kW to 10000 kW) and are located near to the demand, either directly in the distribution system or on the customer's premises[11]. As a result, they are a good alternative for existing electric grids in terms of increasing power dependability and reducing power losses. Because the installation and maintenance of lengthy transmission and distribution lines necessary for power transfer are expensive, DG systems have emerged as a tempting option for remote places. Because they minimise congestion and increase voltage stability, they are increasingly becoming an acceptable alternative for densely populated metropolitan regions [11]. Table 2.1 compares dispersed generation against centralised power generation based on a variety of characteristics.

Table 2.1 Comparison of Distributed and Centralized Generation

Parameter	Centralized Generation	Distributed Generation
Cost	High maintenance and variable cost	Low maintenance and variable cost
Continuous Power	Although centralized power plants have an ability to operate on continuous basis, they reduce system efficiency and increase emission.	Ability to generate peak power or part of it on continuous basis for reliable system operation.
Sustainability	Low sustainability as most of the power generation depends upon conventional energy resources.	High sustainability as most of the power generation depends upon renewable energy resources.
Premium Power	Provision of electricity at higher level power quality and reliability cannot be assured because of high electric power losses	Provision of electricity at improved power quality and reliability as compared to power available from traditional grid.
Peaking Power	Operated at fixed ratings and can address different peak powers	Ability to operate as peak power plant due to flexibility of operation.

DG systems can be used as a stand-alone or grid-connected power plant. In isolated mode, they exclusively service the local load; in grid integrated mode, they also serve the rest of the distribution system's load[12]. DG is beneficial to both utilities and power users, particularly in places where centralised production is not feasible or where transmission network growth is limited. DG is frequently used as a suitable alternative for traditional energy sources in order to satisfy the demand of various load types (industrial, domestic, and commercial). As a result, power system planners and engineers should examine DG as a viable option for optimising system operation.

2.4 Technologies of DG

Small grid-connected or isolated generating units located close to the customer's premises are commonly referred to as DG [24]. The capacity of electricity generation, location, technology, and use in distribution systems are all key characteristics of DG technologies. DG units are often placed near to the load, either directly connected with the consumer or with the distribution system. These machines typically provide electrical power ranging from 1 kW to 1000 kW[13]. To generate power, DG technologies rely on both renewable and non-renewable energy sources. Micro-hydro, wind, biomass, solar PV, tidal, and geothermal power plants are examples of renewable energy-based DG technology. The subsections that follow provide a thorough review of renewable energy resource-based DG technology[14].

2.4.1 Micro Hydro

A micro hydroelectric power plant is a small hydroelectric power station that generates energy in the 5 kW to 100 kW range. As seen in Figure 2.2, these compact power units generate electricity by using the energy of flowing water. For run-of-river power plants, no water storage facility is necessary; instead, a portion of the waterfall or river water is redirected through a penstock and sent to the turbine. The flow of water moves the turbine, which rotates the generator shaft, which generates power[15]. Micro-hydro is a low-cost power generation method since it does not require a dam to store water.

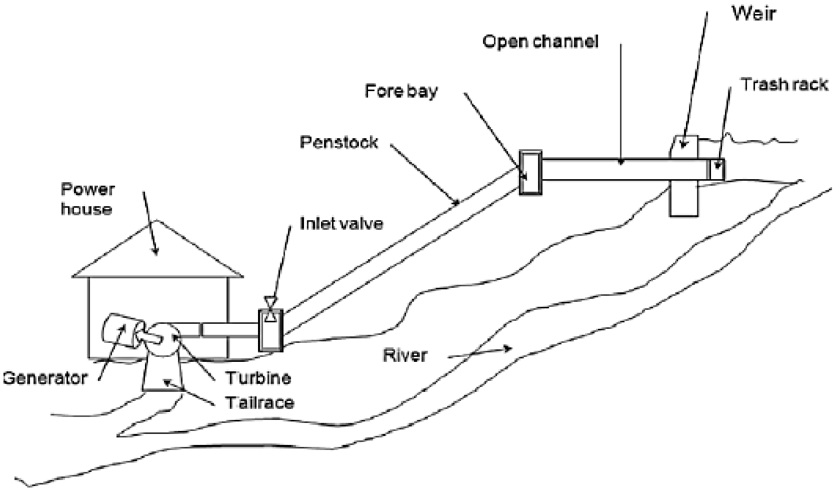

Figure 2.2 Diagram of Micro-hydro Power Plant[16]

2.4.2 Solar Photovoltaic

Solar cells, commonly known as photovoltaic (PV) cells, generate energy directly from sunlight and are divided into three generations[17]. The first-generation solar cells are built of crystalline silicon and are commercially accessible in flat-plate form. They are the leading PV technology. Amorphous silicon thin-film cells are commonly referred to as second-generation solar cells. Because these cells are flexible, they may be used as a top layer for building front walls and rooftop tiles to collect solar energy. Third-generation cells are now in the research and development stage, including many thin-film methods to generate more efficient and cost-effective solar cells[17]. Solar PV technology offers various advantages, including silent operation, minimal pollutants, low fuel costs, and a long operational life. The main drawbacks of this technology are that it is intermittent, only accessible throughout the day, and is weather dependant[18].

In addition, there is a significant investment cost associated with the installation of solar PV technology. The high penetration of solar PV in distribution networks, along with demand variations, causes rapid voltage rises, as well as power swings and large losses. PV cells are classified into three categories based on the nature of the semiconductor (typically silicon) material used in their manufacture: monocrystalline, polycrystalline, and amorphous cells[19].

The solar cells are connected in various quantities to make a photovoltaic panel. PV circuits are placed in a laminated shield of the photovoltaic panel. These PV panels are electrically linked together to form a photovoltaic array, which is the primary source of power generation in any solar system[20].

2.4.3 Wind Turbines

The kinetic energy of the wind is turned into electricity by a wind turbine. Wind is abundant in the environment, making it limitless and redundant. Wind turbines produce no fuel but have a significant installation cost. The output of a wind turbine is not consistent due to the intermittent nature of the wind. This may result in a demand-supply imbalance[21]. As a result, there is a strong probability that the system may have substantial power loss, voltage increase, and stability concerns. Wind turbines are classified into two types: horizontal axis wind turbines (HAWT) and vertical axis wind turbines (VAWT)[21]. In HAWT, the rotor shaft is horizontally positioned, but in VAWT, it is vertically arranged. Because of its comparatively high rotating speed, horizontal axis wind turbines are used in the majority of commercial applications. The rotational speed of VAWT is quite modest, but the fundamental advantage of these turbines is that the blades do not need to be facing the wind[22].

Wind turbines are built in a variety of sizes all over the world[23]. Small wind turbines capture wind energy and use it to power various gadgets and charge batteries. Medium-sized wind turbines are used to generate electricity for isolated household and business demands, whereas giant wind turbines are typically employed in wind forms that are interconnected with the electric grid[21].

2.5 Application of DG

Some power users are currently using DG to satisfy their load demand. Certain power customers use DG to lower the energy costs imposed by the utility, but others use it to satisfy their fundamental need or to eliminate environmental pollution. DG is also used by utilities to improve the efficiency and reliability of their distribution systems. DG units are used to improve power system performance by providing peak power, continuous power, green power and combined heat and power[24].

2.5.1 Continuous Power

DG can be used as a backup power source in the event of a power outage in a big electric power grid. This is accomplished by utilising locally accessible energy resources. Following that, the power system slowly recovers the high priority load in a short period of time and then ensures power supply to low priority customers. In this approach, DG not only provides uninterrupted power supply to customers, but also prevents power system growth in an emergency[25].

2.5.2 Peak Power

The peak power need of the electrical system occurs during a specified time of day. It is preferred that the power system be durable and capable of handling load demand. Conventional power systems, in general, struggle to satisfy peak demand due to long start-up and shut-down times. Furthermore, electric companies often charge a high per unit cost for power consumption during peak hours. As a result, distributed generation has emerged as a viable option for power system architects and operators seeking to meet peak demand at a lower cost. DG plants are often tiny and have a shorter on-line time than traditional power plants. The following are the prominent aspects of DG that make it an appropriate alternative for tackling peak load:

- Low installation cost.
- Less time required for start-up and take full load.
- Low Maintenance cost.

2.5.3 Green Power

Renewable energy resources with zero or extremely low emissions are sometimes referred to as green power DG systems. They are often operated by utilities in order to reduce environmental pollutants during electricity generating. Some distinguishing characteristics of green power DG systems include a positive public image, minimal emissions, electricity dependability, and cheap maintenance costs.

2.5.4 Combined Heat and Power

Combined heat and power (CHP) systems use a Carnot engine to generate both useable heat and electrical energy. Combined heat and power production units, also known as cogeneration power plants, provide the greatest benefits when built in buildings that demand heating, cooling, and electricity all at the same time. Such systems are installed in hospitals, data centres, colleges, hospitals, manufacturing plants, and military bases. To create energy, the textile, sugar, fertiliser, chemical, and petroleum sectors use combined heat and power generation systems. The produced electricity is used to satisfy the relevant industry demand as well as to supply local customers. As a result, the processes engaged in such businesses become more efficient, and the cost of energy per unit is lowered. The key characteristics of CHP are that they have a high heat output while having a low maintenance cost and emissions.

2.6 Impact of DG

Depending on the features of the distributed generators, distribution system, and DG placement, DG can both improve and disrupt distribution feeder control[26]. DG can influence system regulation in a variety of ways, including higher system voltage, DG integration with the distribution system, and interaction with utility equipment.

2.6.1 Impact of DG on Losses

The incorporation of DG systems into distribution networks has a significant influence on electrical power losses. Power losses in distribution systems may be significantly decreased by taking an important parameter of DG location into account. The incorporation of DG to decrease losses is analogous to the installation of capacitors in distribution feeders. Load flow analysis software is used to find the best location for DG. These technologies can determine the best location for DG in a system to reduce power losses[26].

In a distribution system, distributed generation can inject both active power (p) and reactive power (Q), but capacitor banks can only inject reactive power (Q). Because most DG power plants are owned by energy users, power system operators cannot decide the best site for a DG unit. In general, it is considered that installing DG units close to consumers reduces system losses[27]. On the other hand, it may increase the current in local distribution conductors, resulting in unfavourable effects on the conductor's thermal characteristics.

2.6.2 High Voltage Due to DG

In distribution networks, DG units inject an excessive quantity of active and reactive power, resulting in high voltages. The integration of DG can alter the quantity and direction of active and reactive power flows, resulting in changes in the voltage profile of the distribution feeder. High voltages are frequently created by power flows in the opposite direction. In general, when no DG is connected to the distribution system, the voltage received at the load end is less than the transformer main voltage. In comparison to the transformer main side, DG integration may result in reverse power flow and an increase in received voltage at load terminals. DG units with less than 10 MW capacity have a minor influence on the system. If the aggregate capacity of DG units in the distribution system exceeds the threshold level, voltage regulation analysis is required to run the power system within legal limits[26].

2.7 Power flow analysis

In a power system, powers are known rather than currents. Thus, the resulting equations in terms of power, known as the power flow equations, become nonlinear and must be solved by iterative techniques. The backbone of power system analysis and design is power flow studies, often known as load flow. They are required for utility planning, operation, economic scheduling, and power exchange. In addition, many additional analyses, such as transient stability and contingency studies, need power flow analysis[28]. For the solution of nonlinear algebraic equations, numerous iterative approaches are routinely utilised, including Newton Raphson, Gauss-Seidel, and Fast Decouple. These methods are used to solve problems with power flow. The Gauss-Seidel technique was used to create the first algorithm, which solved the load flow problem for a moderately large system for the first time. It did, however, suffer from weak convergence properties. The Newton-Raphson approach was then created to enhance the Gauss-Seidel method's convergence, although it was first regarded to be unfeasible for genuinely scaled systems due to computing issues with massive networks. The solution of a large-dimensional matrix equation is the fundamental issue for the iterative Newton-Raphson technique[29]. The Backward Forward Sweep Power

Flow (BFSPF) approach was employed for this project. In comparison to Newton Raphson, the BFS approach for solving simultaneous nonlinear algebraic equations is less commonly employed. Our investigation of the approach begins with a discussion of how to solve a problem with several equations and variables.

2.8 Backward Forward Sweep Power Flow

Forward backward sweep processes are used in backward forward sweep-based power flow algorithms that take use of the radial network architecture. The forward sweep in this sort of algorithm is mostly the node voltage computation from the sending end to the far end of the feeder and laterals, whereas the reverse sweep is essentially the branch current and power summing from the far end to the sending end. In certain methods, the node voltages are calculated in backward sweeps in addition to the branch current andr power summing[30].

For the load-flow computation, the backward forward sweep power flow technique is an iterative approach in which two computing phases are done at each iteration: A single source network's load flow may be solved repeatedly using two sets of recursive equations. The first set of equations used to calculate the power flow through the branches, starting with the final branch and working backwards to the root node. The other set of equations is used to calculate the voltage magnitude and angle of each node, starting with the root node, and working forward to the final node.

The forward sweep is essentially a voltage drop calculation with updates to the current or power flow. The nodal voltages are updated in a forward sweep from the first layer's branches to the last layers. 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 is preserved constant during forward propagation to the value acquired in the backward walk.

The backward sweep is essentially a current or power flow solution with the ability to update voltage. It starts with the final layer's branches and works its way down to the root node's branches. In the backward propagation computation, the updated effective power flows in each branch are derived by considering the node voltages from the previous iteration. It implies that during backward propagation, the voltage values obtained in the forward path are retained constant, and updated power flows in each branch are transferred backward via the feeder utilising the backward way. This implies that backward propagation begins at the far end node and works its way back to the source node.

2.9 Optimization Technique

Many of algorithm methods that are used to find the minimum or maximum objective function. The algorithm below has been widely used in resolving various difficulties in the application of an electric power system.

I. Ant Colony Optimization (ACO),

II. Simulated Annealing (SA),

III. Mix Integer Optimization by Genetic Algorithm (MIOGA),

IV. Mimetic Algorithm (MA),

V. Differential Evolution (DE)

VI. Particle Swarm Optimization (PSO)

2.10 Mix integer optimization by genetic algorithms (MIOGA)

A genetic algorithm is a search heuristic based on Charles Darwin's natural selection hypothesis. This algorithm reflects natural selection, in which the fittest individuals are chosen for reproduction in order to generate the following generation's progeny[31]. Natural selection is defined as a process that begins with the selection of the fittest individuals from a population. They generate kids who inherit the parents' qualities and are passed on to the next generation. If parents are physically active, their children will be fitter than they are and have a higher chance of surviving. This procedure will continue to iterate until a generation of the fittest individuals is discovered.

This notion can be applied for a search problem. We consider a set of solutions for a problem and select the set of best ones out of them.

Five phases are considered in a genetic algorithm.

- Initial population
- Fitness function
- Selection
- Crossover
- Mutation

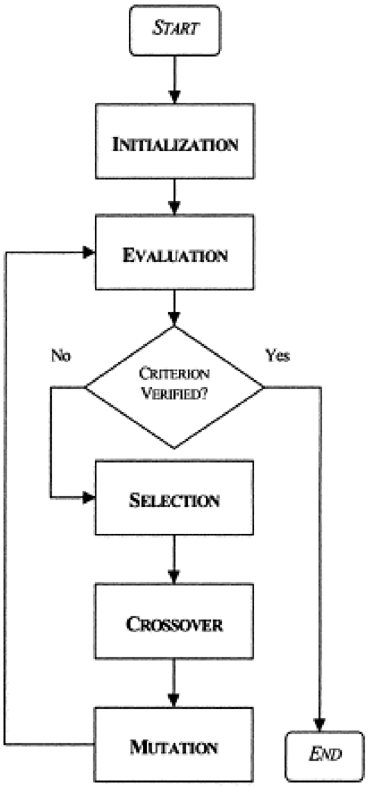

Figure 2.3 Flow chart for Genetic Algorithm

CHAPTER 3

METHODOLOGY

3.1 Introduction

As reviewed in Chapter 2, the uncertainties associated with intermittent renewable power generation and time-varying load demand are required to be addressed for investigating various technical aspects including reliability of distribution system containing renewable DG units. This chapter will provide a detailed overview of the methods that will be utilised to finish and test this project. MATLAB will be used to perform the experiment in this study. After a few iterations, MATLAB will perform all the calculations.

3.2 Overview

To implement the MIOGA algorithm, the technique needed suitable programming. As a result, the project's goal is realised by this programming. Then, to design and develop the programming for the MIOGA algorithm, further programming skills is required. The programme required is the MATLAB software. The MIOGA method was used to solve the IEEE 33-bus problem. The outcome of power losses and the voltage profile using the MIOGA algorithm will be extensively examined once the programme has been written and executed.

3.3 Theoretical purpose method

A variety of approaches and theories for concurrently reforming the distribution network and placing and sizing DGs have been presented in the literature. Most of the past research has attempted to minimise active power losses and enhance the voltage profile. A constant load model is usually assumed in most distributed generation (DG) planning studies. But for this investigation, the load model must have the variation because to get the actual result that want to develop. There are also so many methods that use for solving the investigation such as multi objective index (IMO) method[32], use particle swarm method (PSO)[33] and etc. But for this investigation, the method that use is Mix Integer Optimization by Genetic Algorithms (MIOGA) because The Genetic Algorithm (GA) is a more straightforward method[34]. The backward/forward sweep power flow has been chosen since the network is of the radial kind. The forward sweep is mostly a voltage drop analysis from a feeder's sending end to the far end, whereas the reverse sweep is primarily a current and power summation from the feeder's far end to the sending end. The Newton power flow approach is used to evaluate power flow in the real world [35]. However, in radial distributions with large X/R ratios and DG, this technique is less successful[32]. Furthermore, due to unbalanced activities, radial distribution frequently deteriorates.

3.4 Method of solution

3.4.1 Block diagram

Figure 3.1 shows the full process of developing a radial distribution network with distributed generation in a block diagram.

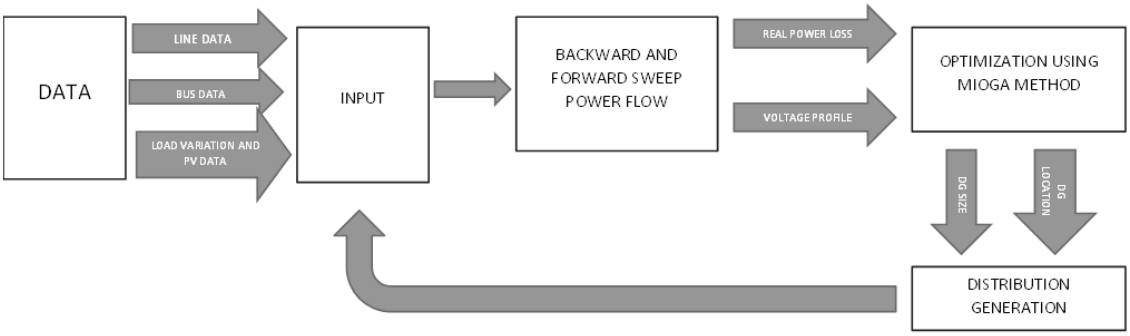

Figure 3.1 Block diagram for the project

The Backward Forward Sweep Power Flow technique is used to solve the power flow problem utilising data from the radial distribution network, such as line data, bus data, load variation data, and PV data. There will be four different scenarios, each with a different amount of DG. Case 1 is a comparison of RDN with and without PVDG for a time-varying residential load model. Case 2 is a study of RDN with and without

PVDG for a time-varying commercial load model. Case 3 is a comparison of RDN with and without PVDG for a time-varying industrial load model. Case 4 is a comparison of RDN for single PVDG and multi-PVDG 33 buses with time variable all load models. The output from the BFSPF (Total Power Loss and Voltage Magnitude) will be used in a Mix Integer Optimization using Genetic Algorithm optimization strategy. The DG location and size will be calculated, and if it does not fit the termination conditions, it will be returned to input.

The amount of DG installations that have an influence on distribution load flows offers the system operator an idea of how to plan for system and network design improvements to meet the demand.

3.4.2 Case study

Case 1: Radial distribution network considers time varying residential load model without PVDG and with PVDG.

Case 2: Radial distribution network considers time varying commercial load model without PVDG and with PVDG.

Case 3: Radial distribution network considers time varying industrial load model without PVDG and with PVDG.

Case 4: Radial distribution network consider time varying all load model single PVDG and multi-PVDG.

3.4.3 Problem formulation

Figure 3.2 explains the flow on the single line of radial distribution network from sending end to receiving end.

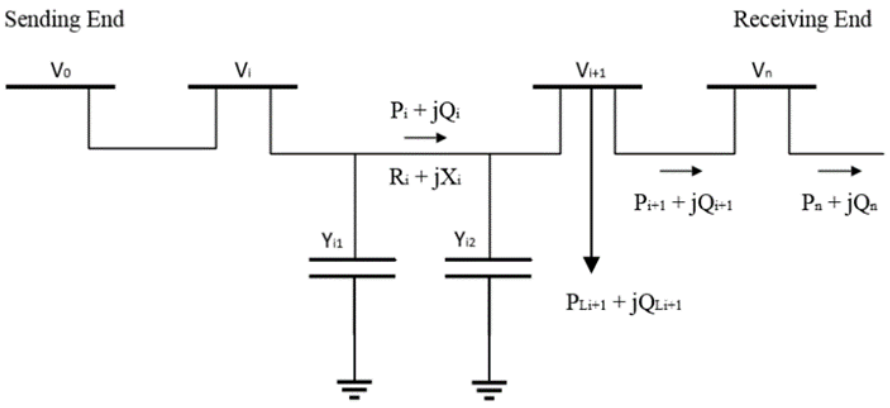

Figure 3.2 Single line of Radial Distribution Network

The following set of simplified recursive equations derived from the single-line diagram presented in figure above are used to calculate power flows in a distribution system[32]. The voltage magnitude and power losses of the 33-bus system may be determined using the power flow analysis. The goal function is to locate the power flow.

$$P_{i+1} = P_i - P_{LOSS,i} - P_{Li+1} \tag{3.1}$$

$$Q_{i+1} = Q_i - Q_{LOSS,i} - Q_{Li+1} \tag{3.2}$$

Where: -

P_i – Real power flowing out of bus

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

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

$$P_{loss}(i,i+1) = R_i \frac{P_i^2 + Q_i^2}{V_i^2} \quad 3.3$$

$$Q_{loss}(i,i+1) = X_i \frac{P_i^2 + Q_i^2}{V_i^2} \quad 3.4$$

Where: -

$P_{loss}(i,i+1)$ – 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

The total power loss of the feeder, $P_{T,loss}(i,i+1)$ may then be determined by summing up the losses of all line sections of the feeder, which is given as

$$P_{T,loss}(i,i+1) = \sum_{i=1}^{n} P_{loss}(i,i+1) \quad 3.5$$

$$Q_{T,loss}(i,i+1) = \sum_{i=1}^{n} Q_{loss}(i,i+1) \quad 3.6$$

Where: -

$P_{T,loss}(i,i+1)$ – Total Real Power Loss in the line section

$Q_{T,loss}(i,i+1)$ – Total Reactive Power Loss in the line section

3.4.4 Backward Forward Sweep Power Flow

The flowchart of Backward Forward Sweep Power Flow (BFSPF) is depicted on Figure 3.3.

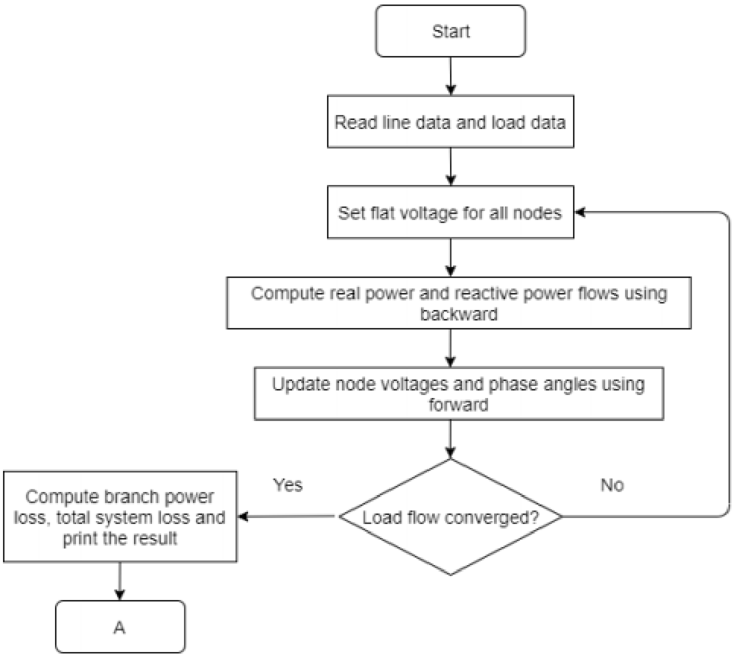

Figure 3.3 Flow Chart of Backward Forward Sweep Power Flow

The backward forward sweep which combined with the MIOGA are the load flow analysis utilized for the optimization process. The voltage magnitude and power losses of the 33-bus radial distribution network will be determined using the power flow analysis. The goal is to reduce the real power loss (P_{loss}) and reactive power loss (Q_{loss}). It also wants to improve the voltage profile on this investigation. Consider Figure 3.3, which shows a branch connecting the nodes i and 'i+1'. Backwards from the previous node, the effective active (Pi) and reactive (Qi) powers of flowing via branch from node i to node 'i+1' may be computed and are given as,

$$P_i = P'_{i+1} + R_i \frac{P'^2_{i+1} + Q'^2_{i+1}}{V^2_{i+1}} \tag{3.7}$$

$$Q_i = Q'_{i+1} + X_i \frac{P'^2_{i+1} + Q'^2_{i+1}}{V^2_{i+1}} \tag{3.8}$$

Where: -

$P'_{i+1} = P_{i+1} + P_{Li+1}$

$Q'_{i+1} = Q_{i+1} + Q_{Li+1}$

P_{Li+1} and Q_{Li+1} are loads that are connected at node ‘i+1’, P_{Li+1} and Q_{Li+1} are the effective real and reactive power flows from node ‘i+1’. The voltage magnitude and angle at each node are calculated in forward direction. Consider a voltage $V_i < \delta_i$ at node ‘i’ and $V_{i+1} < \delta_{i+1}$ at node ‘i+1’, then the current flowing through the branch having an impedance, Z_i=R_i+X_i connected between ‘i’ and ‘i+1’is given as

$$I_i = \frac{(V_i < \delta_{i+1}) - (V_{i+1} < \delta_{i+1})}{Z_i} \qquad 3.9$$

To obtain the voltage and angle of all nodes in a radial distribution system, iteratively employ the magnitude and phase angle equations in a forward manner.

At first, all nodes are considered to have a flat voltage profile, i.e., 1.0 pu. With the updated voltages at each node, the branch powers are determined repeatedly. Power summing is done in the backward sweep and voltages are determined in the forward sweep in the proposed load flow approach.

3.4.5 Mix Integer Optimization Genetic Algorithm

The MIOGA was used to do the optimization. Some of the variables will be restricted to have only integer values. The number of populations have been set to 50. Each individual will be classified and ranked based on the value of their fitness. To reduce power loss, the evaluation will be done using an objective function which it shown at Equation 3.5 and Equation 3.6. MIOGA will go through the steps of selecting, reproducing, and selecting each gene, repeatedly updating them until the best gene is found. The flow chart of MIOGA can be seen at Figure 3.4.

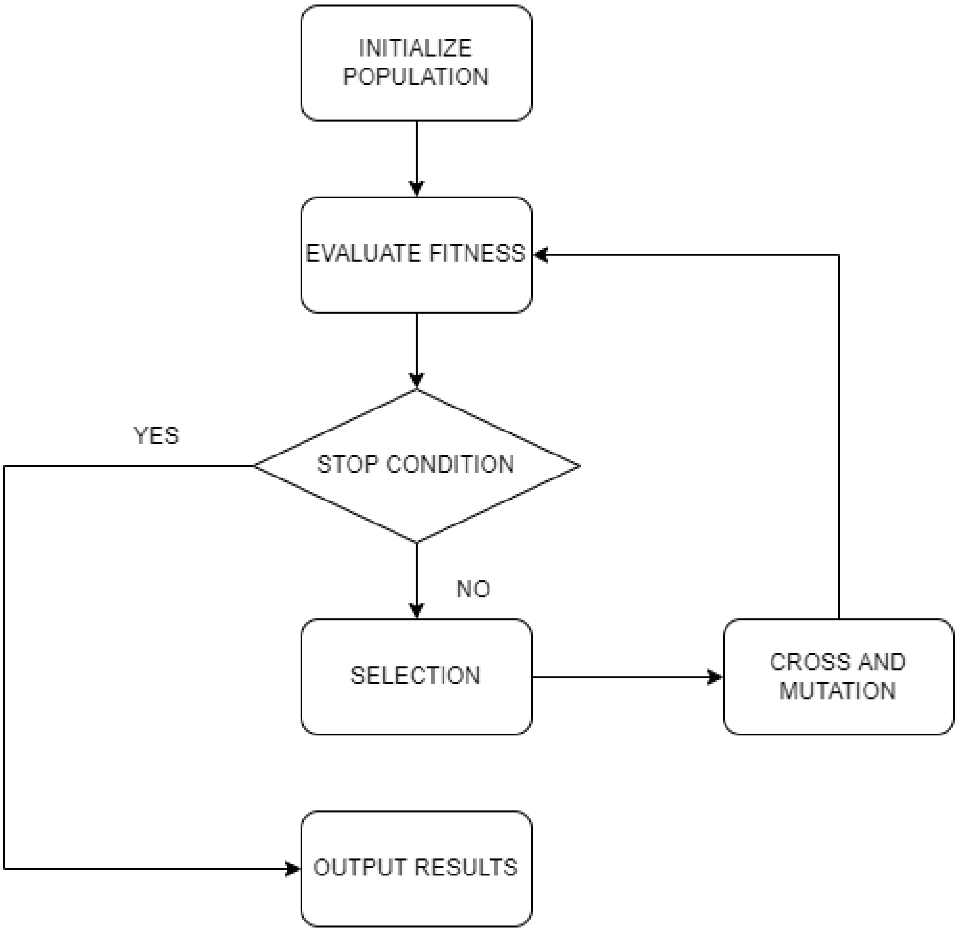

Figure 3.4 Flow chart for MIOGA

This section discusses a method for determining the ideal position and size of DG in the RDN. For real power loss reduction across the RDN, this approach employs an optimization algorithm called as Mix Integer Optimization through Genetic Algorithm (MIOGA)[37]. The load flow in the RDN with DG is evaluated using a backward forward sweep power flow (BFSPF) method. To reduce power loss, the evaluation will be done using an objective function stated in Equation 3.5 and Equation 3.6.

3.5 Design development

3.5.1 Test case investigation

As mentioned earlier, the bus data that use in this work is standard IEEE 33-bus data. In this data, we can get the load data and line data for each bus.

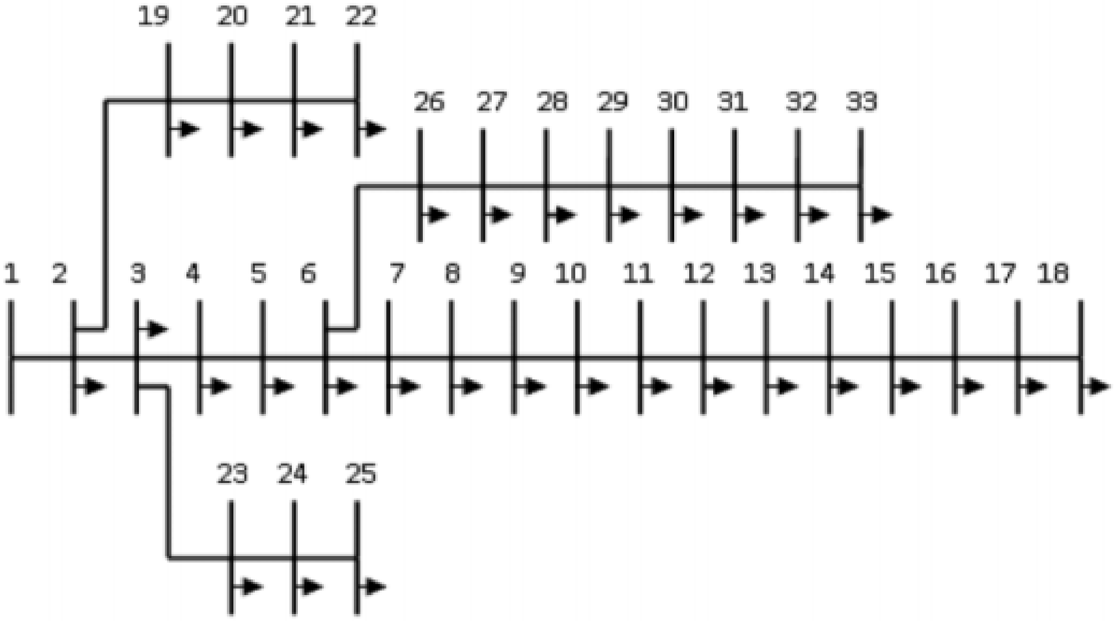

Figure 3.5 IEEE 33-bus Radial Distribution Network

3.5.2 Load data

On load data, the real power, P and reactive power, Q for each bus from bus 1 to bus 33 are tabulated in Table 3.1.

Table 3.1 IEEE 33-bus load data

Bus No	Real Power, P (KW)	Reactive Power, Q (KVAR)
1	-	-
2	100	60
3	90	40
4	120	80
5	60	30
6	60	100
7	200	100
8	60	20
9	60	20
10	45	20

11	60	30
12	60	35
13	120	35
14	60	80
15	60	10
16	60	20
17	60	20
18	90	40
19	90	40
20	90	40
21	90	40
22	90	40
23	90	50
24	420	200
25	420	200
26	60	25
27	60	25
28	60	20
29	120	70
30	200	600
31	150	70
32	210	100
33	60	40

3.5.3 Line Data

Based on the line data IEEE 33-bus radial distribution network, the value of resistance, R and the impedance, X from sending bus to the receiving bus are tabulated in Table 3.2.

Table 3.2 IEEE 33-bus line data

Bus No	Sending Bus	Receiving Bus	R	X
1	1	2	0.0922	0.0470
2	2	3	0.4930	0.2511
3	3	4	0.3660	0.1864
4	4	5	0.3811	0.1941
5	5	6	0.8190	0.7070

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

3.5.4 Load variation and PV data

Table 3.3 shows the load variation data for the 3 major load model in the urban area. The data source is from TNB distribution Petaling Jaya.

Table 3.3 Urban area load data.

Time	Industrial (p.u)	Commercial (p.u)	Residential (p.u)
1	0.2405	0.1281	0.5968
2	0.2315	0.1247	0.5498
3	0.2262	0.1213	0.5157
4	0.2199	0.1165	0.4814
5	0.2167	0.1138	0.4567
6	0.2142	0.1136	0.4550
7	0.2171	0.1267	0.4772
8	0.2915	0.2910	0.4300
9	0.4848	0.5281	0.3923
10	0.5732	0.6648	0.3936
11	0.5912	0.6882	0.3900
12	0.6152	0.6916	0.3898
13	0.5437	0.6605	0.3957
14	0.6039	0.6410	0.3900
15	0.6225	0.6978	0.4092
16	0.6257	0.6973	0.4351
17	0.6279	0.6621	0.4356
18	0.5798	0.4995	0.4380
19	0.4936	0.3365	0.4553
20	0.4499	0.2687	0.5367
21	0.3982	0.1976	0.5858
22	0.3632	0.1756	0.6107
23	0.3024	0.1481	0.6493
24	0.2682	0.1348	0.6341

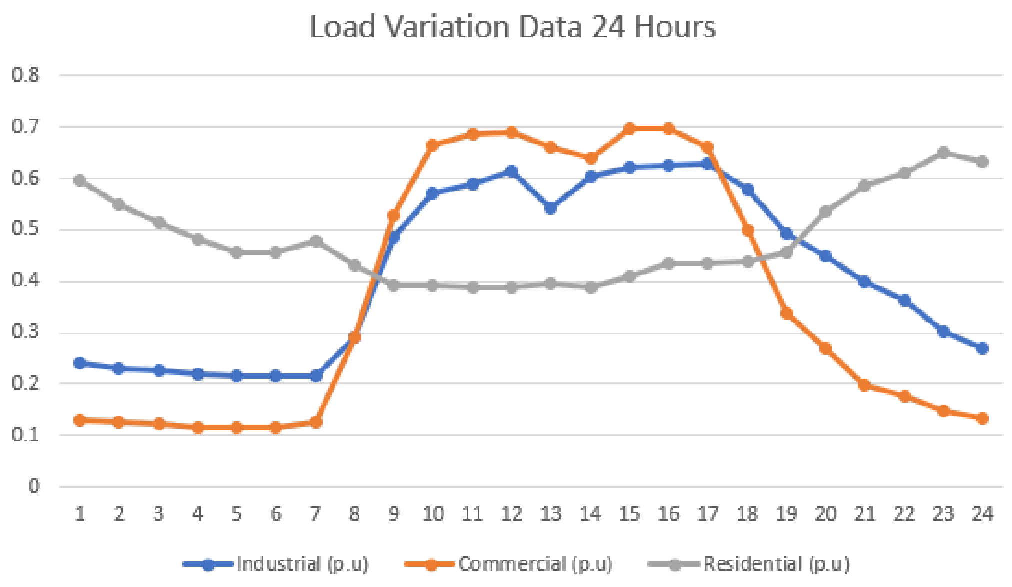

Figure 3.6 Urban area load data in graph.

The table 3.4 shows the PV output power solar panel. The PV model is based on article in [32].

Table 3.4 PV data

Time	PV (kW per panel)
1	0
2	0
3	0
4	0
5	0
6	0
7	0
8	0
9	0.0134
10	0.0272
11	0.0362
12	0.0506
13	0.0557
14	0.0638
15	0.0538
16	0.0452

17	0.0316
18	0.0156
19	0
20	0
21	0
22	0
23	0
24	0

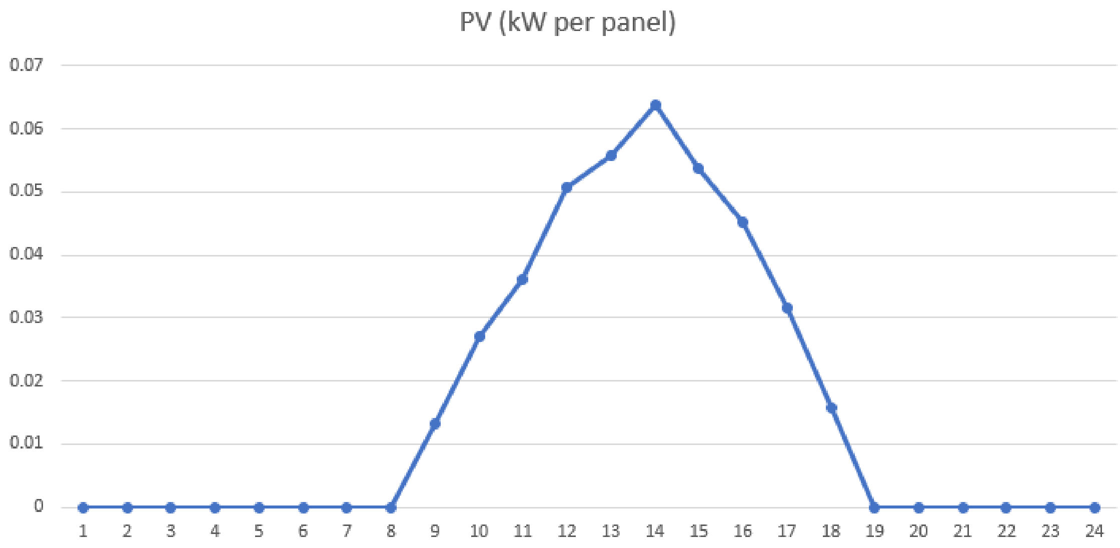

Figure 3.7 PV data in graph[32]

3.5.5 Flow chart of investigation

Figure 3.8 depicts the full process of developing a radial distribution network with scattered generation in a flow chart diagram.

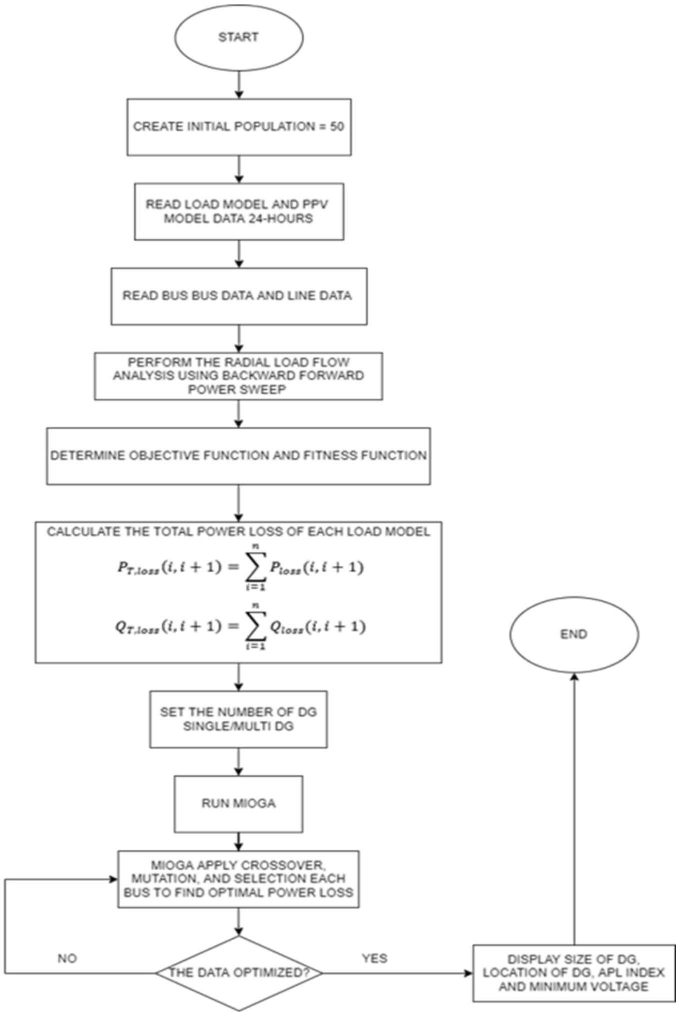

Figure 3.8 Overall Flow Chart Diagram

The Backward Forward Sweep Power Flow technique is used to address the power flow problem utilising data from the radial distribution network, such as line and bus data. The load fluctuation and PV statistics were also used as input for the DG process simulation. There will be 4 cases, each with a different condition being tested. For case 1 until case 3, I do the comparison for load model (residential, commercial, and industrial) without PVDG and with PVDG 33 bus. The simulation is run by single DG using MIOGA method. After that, case 4 is comparison for all load model PVDG 33 bus and it run by multi-DG. The simulation is run by single PVDG and multi-PVDG using MIOGA method. The Total Power loss and voltage minimum will be use in optimization scheme using backward and forward sweep. The DG location and size of

DG will be determined after the run of MIOGA. Lastly, make the comparison for the system work without DG, single DG, and multi-PVDG installation.

To mimic the research, the following parameters were employed:

- Population size = 50
- Maximum iteration count = 50

The following are the stages involved in the suggested technique:

1. Create the initial population of 50 individuals.
2. Insert the load model data for residential, commercial, and industrial for 24-hours.
3. Insert the PPV data for 24-hours.
4. Add the RDN parameter, as well as the line and bus data.
5. RDN is performed to evaluate the fitness function. The minimal total power losses define the fitness function.
6. Calculate the total power losses each load to get the PT,loss and QT,loss.
7. Set the number of DG to identify the size and location.
8. Run MIOGA. MIOGA reduces power loss by connecting the DG to the target bus after determining the minimum voltage and maximum branch losses. To make the decision, it will also do the crossover and mutation.
9. If the data not converged, back to step 8 to update the fitness function. If converged, go to next step.
10. The best solution is printed. The ideal position includes the DG optimal size and placement.
11. APL index is calculated, and the result printed out.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

Backward Forward Sweep Power Flow (BFSPF) method has successfully used in solving load flow problem. The test investigation is applied to IEEE 33-bus system before and after optimization with PVDG. The purpose of this project is to minimize the active power system loss and voltage deviation of the distribution network with optimal placement and sizing of distribution generation in distribution networks using Mix Integer Optimization by Genetic Algorithm (MIOGA) and Backward Forward Sweep Power Flow (BFSPF) method considering time varying load for each load model.

In this study, four case studies are considered which three of them is comparison of RDN considering time varying load for without PVDG and with PVDG installation. One of the cases is focusing for RDN consider time varying load for single PVDG and multi-PVDG installation. Analysis of result is made based on result for all cases.

4.2 Radial Distribution Network Considers Time-Varying Load Model without PVDG.

Figure 4.1 shows the variation of voltage in the different load variations for urban area which occur at critical bus (bus 18).

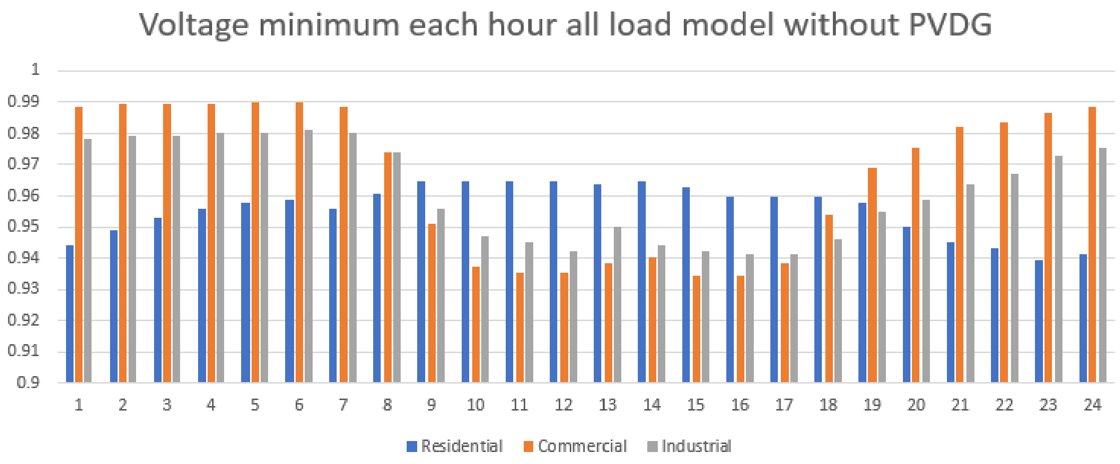

Figure 4.1 Voltage magnitude for all load model for urban area at critical bus (bus 18) without PVDG.

4.3 Case 1: Radial distribution network considers time varying residential load model without PVDG and with PVDG.

4.3.1 Backward and forward sweep power flow method

Table 4.1 shows the comparison of voltage magnitude for residential load urban area without PVDG and with PVDG. It occurs at critical bus (bus 18).

Table 4.1 Voltage Magnitude of 33-bus system without PVDG and with PVDG for case 1

HOURS	CASE 1	
	WITHOUT DG	WITH DG
1	0.9443	0.9587
2	0.9492	0.9621
3	0.953	0.9646
4	0.9559	0.9670
5	0.9578	0.9687
6	0.9587	0.9689
7	0.9559	0.9673
8	0.9606	0.9706
9	0.9644	0.9733
10	0.9644	0.9732

11	0.9644	0.9734
12	0.9644	0.9734
13	0.9635	0.9730
14	0.9644	0.9734
15	0.9625	0.9721
16	0.9597	0.9703
17	0.9597	0.9702
18	0.9597	0.9701
19	0.9578	0.9688
20	0.9501	0.9631
21	0.9453	0.9595
22	0.9433	0.9577
23	0.9394	0.9549
24	0.9414	0.9560

Table 4.2 Performance of the method without PVDG case 1

Total P loss (kW)	Total Q loss (kVar)	Minimum voltage (p.u)
78.9673	53.4727	0.9394

Table 4.3 Performance of the method with PVDG case 1

Total P loss (kW)	Total Q loss (kVar)	Minimum voltage (p.u)
47.5815	34.1486	0.9549

Using the backward forward sweep power flow method, the voltage, total real, and reactive power losses of a 33-bus system are calculated. Table 4.2 and Table 4.3 shows the overall power loss for RDN without PVDG and with PVDG. Table 4.1 shows the voltage magnitude of this system at various hours. At hour 23, the proposed system's lowest voltage is 0.9394 p.u. In radial distribution networks, the system efficiency of backward/forward sweep was provided. The distribution power flow is carried by the iterative backward and forward propagation equation. Backward propagation was used to calculate the power of each branch. The voltage magnitudes at each node are determined in forward propagation. The iterations have a high chance of convergent quickly. The findings of the IEEE 33 Bus Test System have been tabulated. The proposed load flow approach was shown to be excellent for aspects such as rapid convergence and radial structure.

4.3.2 Mix integer optimization via genetic algorithms

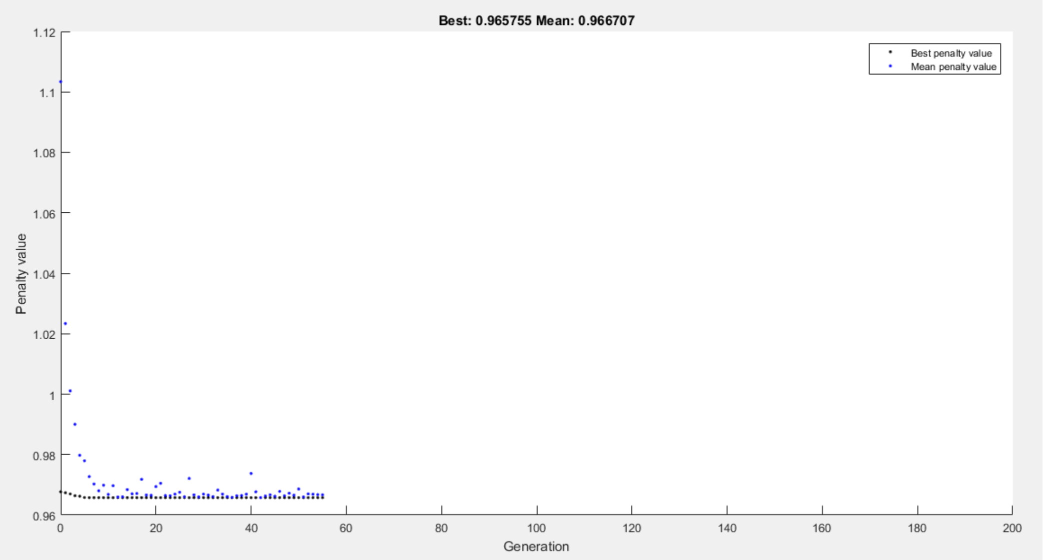

Figure 4.2 The convergence performance for case 1

Figure 4.2 shows the fitness value computed by MIOGA in MATLAB. The optimization was run by installing a 1.6493 kW PVDG at bus no. 6. As for case 1, consider time varying residential load depicts the difference in bus voltage magnitude at different bus and different hours between the radial distribution network with PVDG installation that shown at Figure 4.2. The simulated results obtained from MATLAB are shown in Table 4.4 below.

Table 4.4 Comparison residential load without PVDG and with PVDG (case 1)

Parameters	Method	
	Without PVDG	With PVDG (MIOGA) Single DG
	Residential	Residential
Optimal DG size (kW)	-	1.6493

Optimal DG location	-	6
APL index	-	0.5971
Total P loss (kW)	78.9673	47.5815
Total Q loss (kVar)	53.4727	34.1486
P loss reduction (%)	-	39.75
Q loss reduction (%)	-	36.14
Minimum voltage (p.u)	0.9394	0.9549
Minimum voltage at hours	23	23
Minimum voltage at bus	18	18

Table 4.4 show that the DG size is 1.6493 kW which is located at bus 6. It also shows that the total real power is reduce 39.75% which from 78.9673 kW to 47.5815 kW. The reactive power loss also reduces 36.14% from 53.4727 kVar without DG and 34.1486 kVar with PVDG installation. The APL index is 0.5971 after PVDG installation. The minimum voltage per unit at critical bus (bus 18) also is gain from 0.9394 p.u to 0.9549 p.u and it happened at hour 23.

Figure 4.3 illustrates the contrast of the bus voltage magnitude each hour at critical bus (bus 18) between the radial distribution network with and without DG. Therefore, the development of DG helps in reducing total power loss for 33-bus distribution network and at the same time improve the voltage profile.

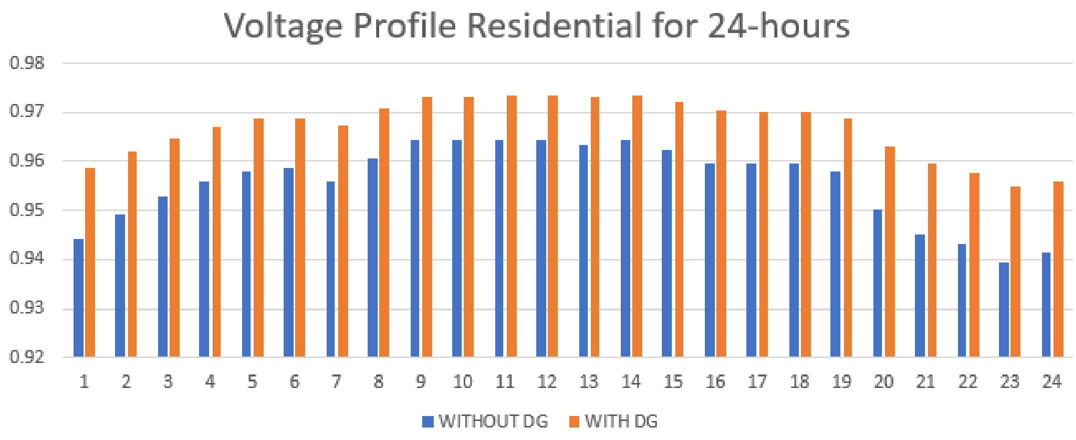

Figure 4.3 Comparison of voltage values case 1 at critical bus (bus 18) before and after PVDG

4.4 Case 2: Radial distribution network considers time varying commercial load model without PVDG and with PVDG.

4.4.1 Backward and forward sweep power flow method

Table 4.5 shows the comparison of voltage magnitude for commercial load urban area without PVDG and with PVDG. It occurs at critical bus (bus 18).

Table 4.5 Voltage Magnitude of 33-bus system without PVDG and with PVDG for case 2

HOURS	CASE 2	
	WITHOUT DG	WITH DG
1	0.9884	0.9933
2	0.9893	0.9935
3	0.9893	0.9937
4	0.9893	0.9939
5	0.9902	0.9941
6	0.9902	0.9941
7	0.9884	0.9934
8	0.9737	0.9847
9	0.9511	0.9717
10	0.9374	0.9641
11	0.9354	0.9627

12	0.9354	0.9625
13	0.9384	0.9643
14	0.9404	0.9654
15	0.9345	0.9622
16	0.9345	0.9622
17	0.9384	0.9642
18	0.954	0.9733
19	0.9691	0.9822
20	0.9756	0.9859
21	0.982	0.9897
22	0.9838	0.9908
23	0.9866	0.9923
24	0.9884	0.9930

Table 4.6 Performance of the method without PVDG case 2

Total P loss (kW)	Total Q loss (kVar)	Minimum voltage (p.u)
3.1321	2.1182	0.9345

Table 4.7 Performance of the method with PVDG case 2

Total P loss (kW)	Total Q loss (kVar)	Minimum voltage (p.u)
1.8964	1.3988	0.9622

The backward forward sweep power flow method is used to calculate the voltage, total real, and reactive power losses of a 33-bus system. Tables 4.6 and 4.7 illustrate the overall power loss for RDN without and with PVDG. Table 4.5 shows the voltage magnitude of this system at various hours. During hours 15-16, the proposed system's lowest voltage is 0.9345 p.u. In radial distribution networks, the system efficiency of backward/forward sweep was provided. The distribution power flow is carried by the iterative backward and forward propagation equation. Backward propagation was used to calculate the power of each branch. The voltage magnitudes at each node are determined by forward propagation. The iterations have a strong chance of converging fast. The findings of the IEEE 33 Bus Test System have been tabulated. The proposed load flow approach was shown to have exceptional properties such as rapid convergence and radial structure.

4.4.2 Mix integer optimization by genetic algorithms

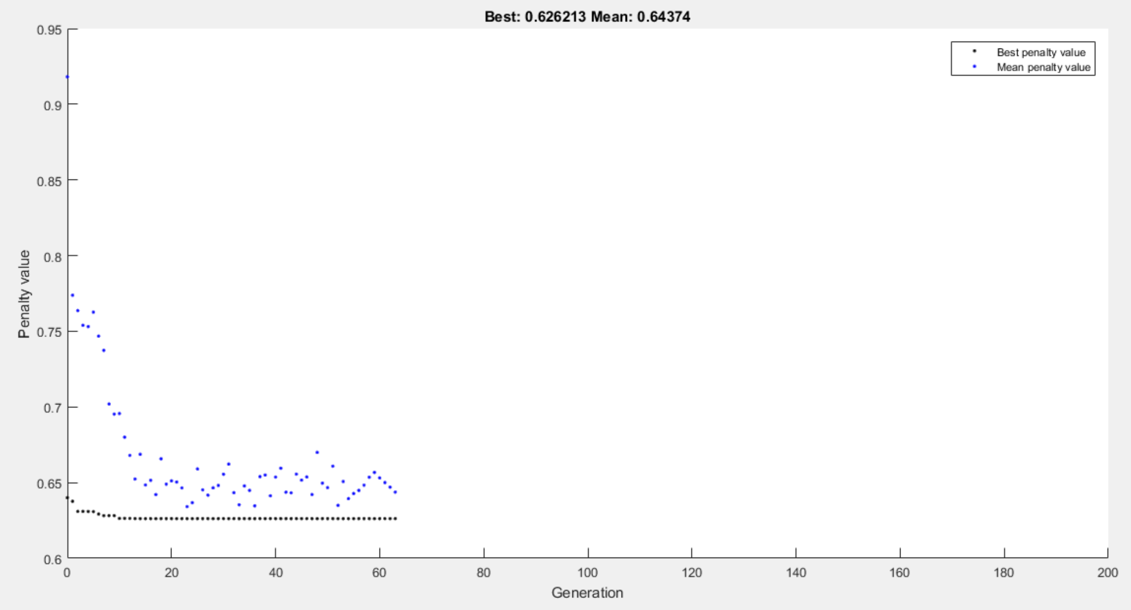

Figure 4.4 The convergence performance for case 2

The fitness value determined by MIOGA in MATLAB is shown in Figure 4.4. The optimization was carried out with the installation of a 2.7464 kW PVDG at bus number 6. Table 4.8 below shows the simulated findings achieved using MATLAB.

Table 4.8 Comparison commercial load without PVDG and with PVDG (case 2)

Parameters	Method	
	Without PVDG	With PVDG (MIOGA) Single DG
	Commercial	Commercial
Optimal DG size (kW)	-	2.7464
Optimal DG location	-	6
APL index	-	0.544

Total P loss (kW)	3.1321	1.8964
Total Q loss (kVar)	2.1182	1.3988
P loss reduction (%)	-	39.45
Q loss reduction (%)	-	33.96
Minimum voltage (p.u)	0.9345	0.9622
Minimum voltage at hours	15-16	15-16
Minimum voltage at bus	18	18

The DG size is 2.7464 kW, according to Table 4.8, and it is placed at bus 6. It also reveals that total actual power has decreased by 39.45%, from 3.1321 kW to 1.8964 kW. The reactive power loss is also reduced by 33.96 percent, going from 2.1182 kVar without DG to 1.3988 kVar with PVDG. After PVDG installation, the APL index is 0.544. After PVDG installation, the minimum voltage per unit at crucial bus (bus 18) increased from 0.9345 p.u. to 0.9622 p.u., which occurred between hours 15 and 16.

The difference in bus voltage magnitude per hour at crucial bus (bus 18) between the radial distribution network with and without DG is depicted in Figure 4.5. As a result, the development of DG aids in the reduction of total power loss in the 33-bus distribution network while also improving the voltage profile.

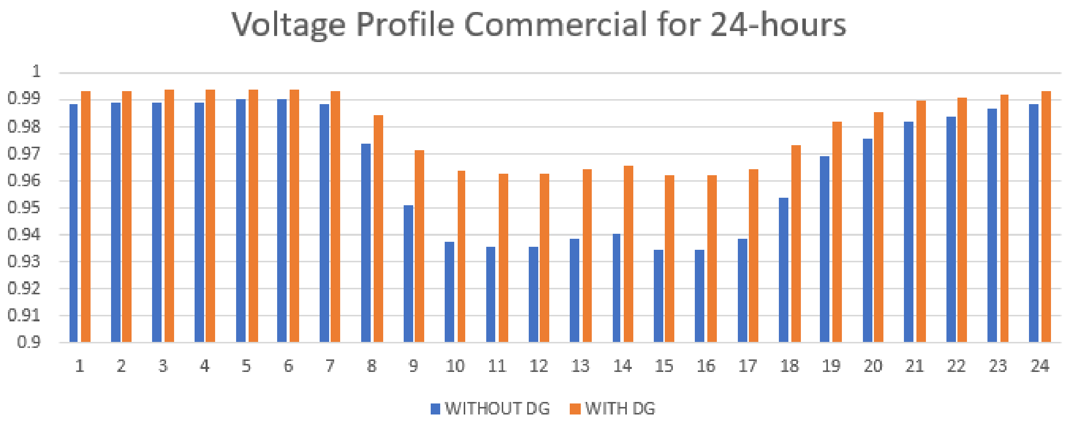

Figure 4.5 Comparison of voltage values case 2 at critical bus (bus 18) before and after PVDG

4.5 Case 3: Radial distribution network considers time varying industrial load model without PVDG and with PVDG.

4.5.1 Backward and forward sweep power flow method

Table 4.9 shows the comparison of voltage magnitude for industrial load urban area without PVDG and with PVDG. It occurs at critical bus (bus 18).

Table 4.9 Voltage Magnitude of 33-bus system without PVDG and with PVDG for case 3

HOURS	CASE 3	
	WITHOUT DG	WITH DG
1	0.9784	0.9864
2	0.9793	0.9869
3	0.9793	0.9872
4	0.9802	0.9876
5	0.9802	0.9878
6	0.9811	0.9879
7	0.9802	0.9878
8	0.9737	0.9835
9	0.9559	0.9722
10	0.9472	0.9669
11	0.9453	0.9658
12	0.9423	0.9644

13	0.9501	0.9687
14	0.9443	0.9651
15	0.9423	0.9639
16	0.9414	0.9638
17	0.9414	0.9636
18	0.9462	0.9665
19	0.9549	0.9717
20	0.9587	0.9743
21	0.9635	0.9773
22	0.9672	0.9793
23	0.9728	0.9829
24	0.9756	0.9848

Table 4.10 Performance of the method without PVDG case 3

Total P loss (kW)	Total Q loss (kVar)	Minimum voltage (p.u)
13.7703	9.3157	0.9414

Table 4.11 Performance of the method with PVDG case 3

Total P loss (kW)	Total Q loss (kVar)	Minimum voltage (p.u)
7.504	5.513	0.9636

The voltage, total real, and reactive power losses of a 33-bus system are computed using the backward forward sweep power flow method. The overall power loss for RDN without PVDG and with PVDG is shown in Tables 4.10 and 4.11. The voltage magnitude of this system is shown in Table 4.9 at various hours. The planned system's lowest voltage is 0.9414 p.u. during hour 16-17. The system efficiency of backward/forward sweep was presented in radial distribution networks. The iterative backward and forward propagation equation carries the distribution power flow. The power of each branch was calculated via backward propagation. Forward propagation determines the voltage magnitudes at each node. The iterations have a good possibility of quickly converging. The IEEE 33 Bus Test System results have been tabulated. Rapid convergence and radial structure were demonstrated to be outstanding features of the suggested load flow technique.

4.5.2 Mix integer optimization by genetic algorithms

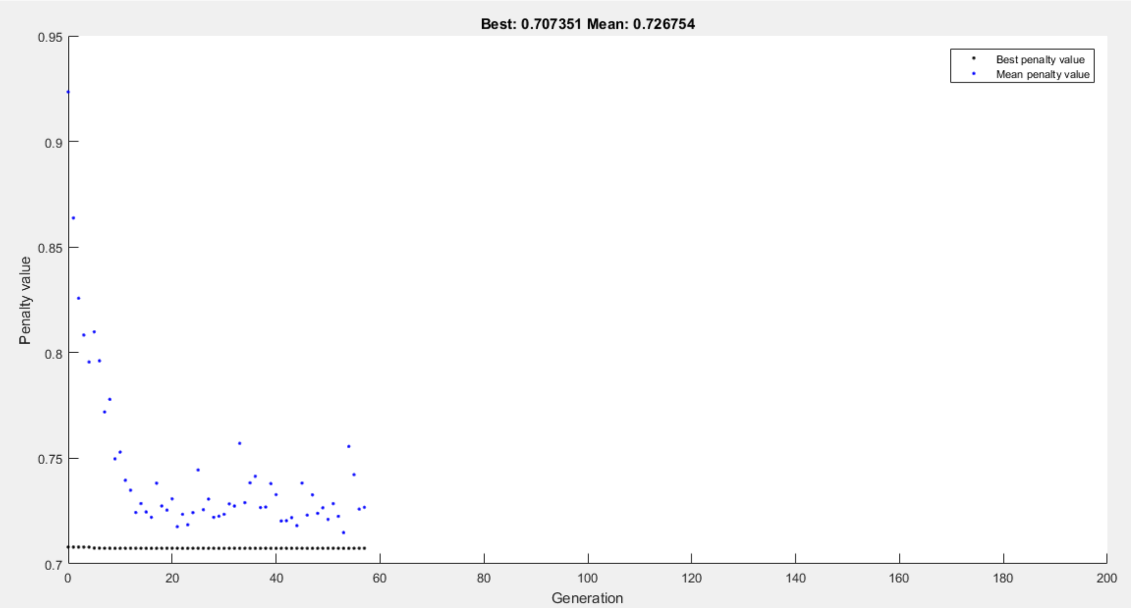

Figure 4.6 The convergence performance for case 3

Figure 4.6 shows the fitness value computed by MIOGA in MATLAB. The optimization was run by installing a 2.4579 kW PVDG at bus no. 6. The simulated results obtained from MATLAB are shown in Table 4.12 below.

Table 4.12 Comparison industrial load without PVDG and with PVDG (case 3)

Parameters	Method	
	Without PVDG	With PVDG (MIOGA) Single DG
	Industrial	Industrial
Optimal DG size (kW)	-	2.4579
Optimal DG location	-	6
APL index	-	0.5441
Total P loss (kW)	13.7703	7.504
Total Q loss (kVar)	9.3157	5.513

P loss reduction (%)	-	45.51
Q loss reduction (%)	-	40.82
Minimum voltage (p.u)	0.9414	0.9636
Minimum voltage at hours	16-17	17
Minimum voltage at bus	18	18

Table 4.12 show that the DG size is 2.4579 kW which is located at bus 6. It also shows that the total real power is reduce 45.51% which from 13.7703 kW to 7.504 kW. The reactive power loss also reduces 40.82% from 9.3157 kVar without DG and 5.513 kVar with PVDG installation. The APL index is 0.5441 after PVDG installation. The minimum voltage per unit at critical bus (bus 18) also is gain from 0.9414 p.u to 0.9636 p.u after PVDG installation and it happened at hour 17.

Figure 4.7 illustrates the contrast of the bus voltage magnitude each hour at critical bus (bus 18) between the radial distribution network with and without DG. Therefore, the development of DG helps in reducing total power loss for 33-bus distribution network and at the same time improve the voltage profile.

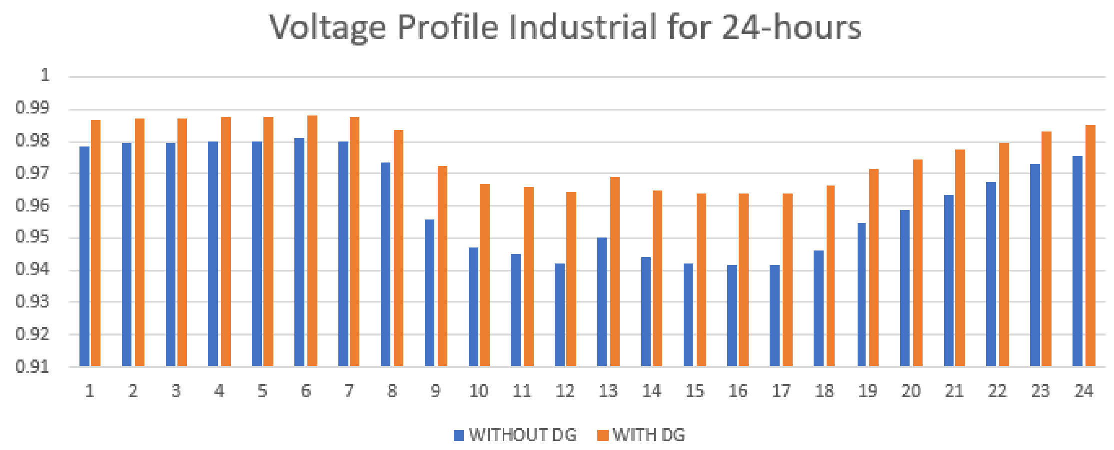

Figure 4.7 Comparison of voltage values case 3 at critical bus (bus 18) before and after PVDG

4.6 Case 4: Radial distribution network consider time varying all load model single PVDG and multi-PVDG.

4.6.1 Backward and forward sweep power flow method

Table 4.13 shows the comparison of voltage magnitude for all load urban area with single PVDG and multi-PVDG. All critical bus for single PVDG is located at bus 18 but for multi-PVDG is happened at different buses. Residential is located at bus 18 as the critical bus while commercial and industrial located at bus 33.

Table 4.13 Voltage Magnitude of 33-bus system single PVDG and multi PVDG for case 4

CASE 4						
	SINGLE PVDG			MULTI PVDG		
	RESIDENTIAL	COMMERCIAL	INDUSTRIAL	RESIDENTIAL	COMMERCIAL	INDUSTRIAL
1	0.9587	0.9933	0.9864	0.9775	0.9958	0.9913
2	0.9621	0.9935	0.9869	0.9793	0.9959	0.9916
3	0.9646	0.9937	0.9872	0.9806	0.9960	0.9918
4	0.9670	0.9939	0.9876	0.9820	0.9962	0.9920
5	0.9687	0.9941	0.9878	0.9829	0.9963	0.9922
6	0.9689	0.9941	0.9879	0.9830	0.9963	0.9923
7	0.9673	0.9934	0.9878	0.9821	0.9958	0.9921

8	0.9706	0.9847	0.9835	0.9839	0.9903	0.9894
9	0.9733	0.9717	0.9722	0.9854	0.9822	0.9822
10	0.9732	0.9641	0.9669	0.9853	0.9774	0.9788
11	0.9734	0.9627	0.9658	0.9855	0.9765	0.9781
12	0.9734	0.9625	0.9644	0.9855	0.9764	0.9772
13	0.9730	0.9643	0.9687	0.9852	0.9775	0.9799
14	0.9734	0.9654	0.9651	0.9855	0.9782	0.9776
15	0.9721	0.9622	0.9639	0.9847	0.9762	0.9769
16	0.9703	0.9622	0.9638	0.9837	0.9762	0.9768
17	0.9702	0.9642	0.9636	0.9837	0.9775	0.9767
18	0.9701	0.9733	0.9665	0.9836	0.9832	0.9786
19	0.9688	0.9822	0.9717	0.9830	0.9888	0.9818
20	0.9631	0.9859	0.9743	0.9798	0.9911	0.9835
21	0.9595	0.9897	0.9773	0.9779	0.9935	0.9854
22	0.9577	0.9908	0.9793	0.9770	0.9942	0.9868
23	0.9549	0.9923	0.9829	0.9755	0.9951	0.9890
24	0.9560	0.9930	0.9848	0.9761	0.9956	0.9903

Table 4.14 Performance of the method single PVDG case 4

LOAD	Total P loss (kW)	Total Q loss (kVar)	Minimum voltage (p.u)
RESIDENTIAL	47.5815	34.1486	0.9549
COMMERCIAL	1.8964	1.3988	0.9622
INDUSTRIAL	7.504	5.513	0.9636

Table 4.15 Performance of the method multi PVDG case 4

LOAD	Total P loss (kW)	Total Q loss (kVar)	Minimum voltage (p.u)
RESIDENTIAL	32.4986	22.8209	0.9755
COMMERCIAL	1.6149	1.1501	0.9762
INDUSTRIAL	6.0027	4.2754	0.9767

Using the backward forward sweep power flow method, the voltage, total real, and reactive power losses of a 33-bus system are calculated. Table 4.14 and Table 4.15 shows the overall power loss for RDN without PVDG and with PVDG. Table 4.13 shows the voltage magnitude of this system at various hours. For residential load with single PVDG, the proposed system's lowest voltage is 0.9549 p.u while with multi

PVDG (3 DG) is 0.9755 p.u. For commercial load with single PVDG, the proposed system's lowest voltage is 0.9622 p.u while with multi PVDG (3 DG) is 0.9762 p.u. For industrial load with single PVDG, the proposed system's lowest voltage is 0.9636 p.u while with multi PVDG (3 DG) is 0.9767 p.u. In radial distribution networks, the system efficiency of backward/forward sweep was provided. The distribution power flow is carried by the iterative backward and forward propagation equation. Backward propagation was used to calculate the power of each branch. The voltage magnitudes at each node are determined in forward propagation. The iterations have a high chance of convergent quickly. The findings of the IEEE 33 Bus Test System have been tabulated. The proposed load flow approach was shown to be excellent for aspects such as rapid convergence and radial structure.

4.6.2 Mix integer optimization by genetic algorithms

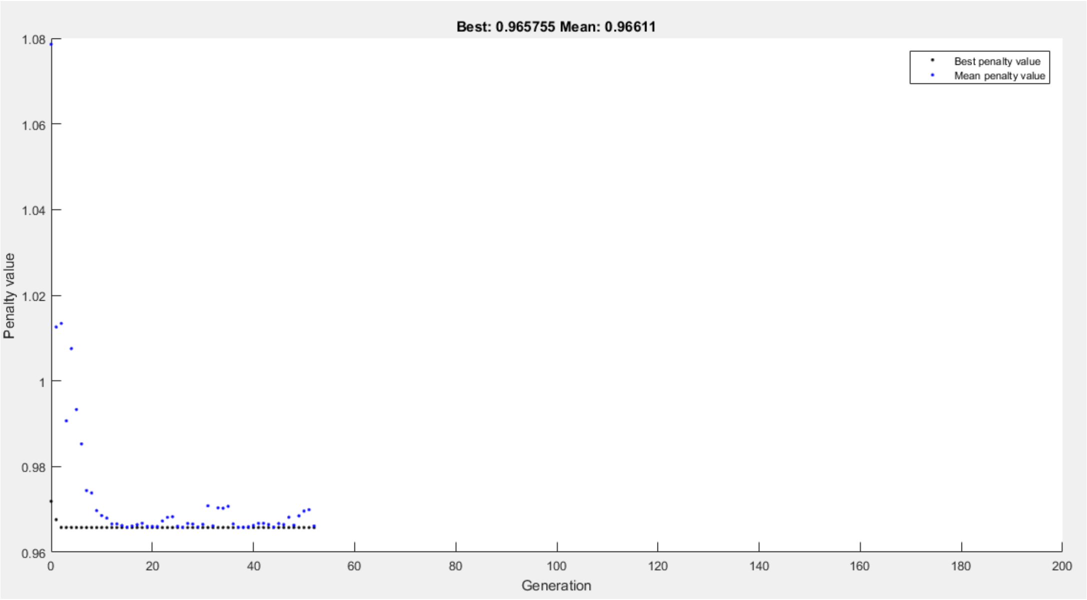

Figure 4.8 The convergence performance for residential case 4

The fitness value determined by MIOGA in MATLAB is shown in Figure 4.8. At bus no. 6,14,31, the optimization was carried out by installing 1.6493 kW, 0.456 kW, and 0.3767 kW PVDGs.

Table 4.16 shows the simulated findings achieved using MATLAB.

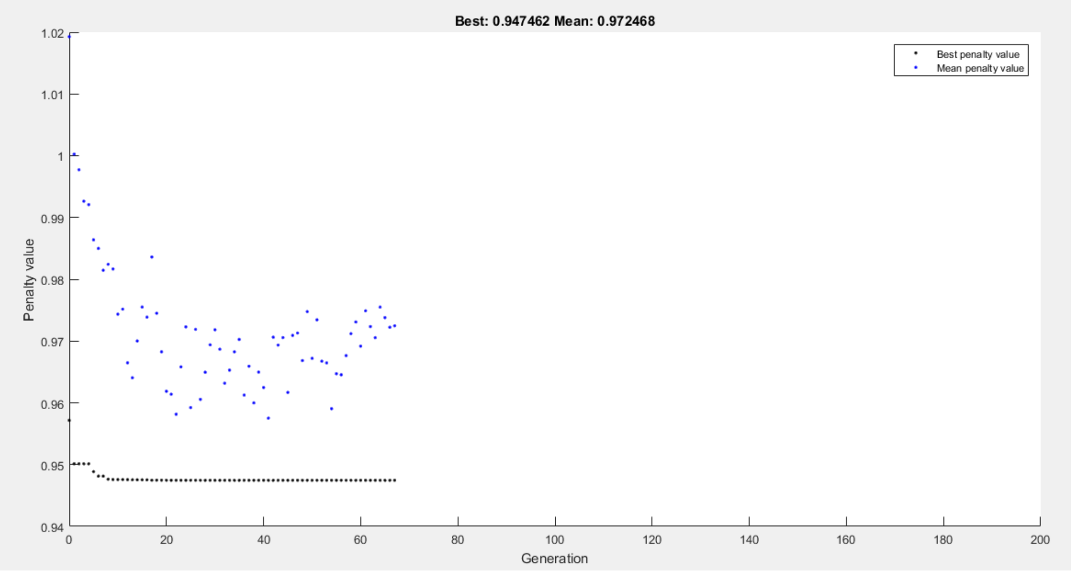

Figure 4.9 The convergence performance for commercial case 4

Figure 4.9 shows the fitness value computed by MIOGA in MATLAB. The optimization was run by installing a 2.7464 kW, 0.4423 kW and 0.5263 kW PVDG at bus no. 6,16,25. The simulated results obtained from MATLAB are shown in Table 4.16 below.

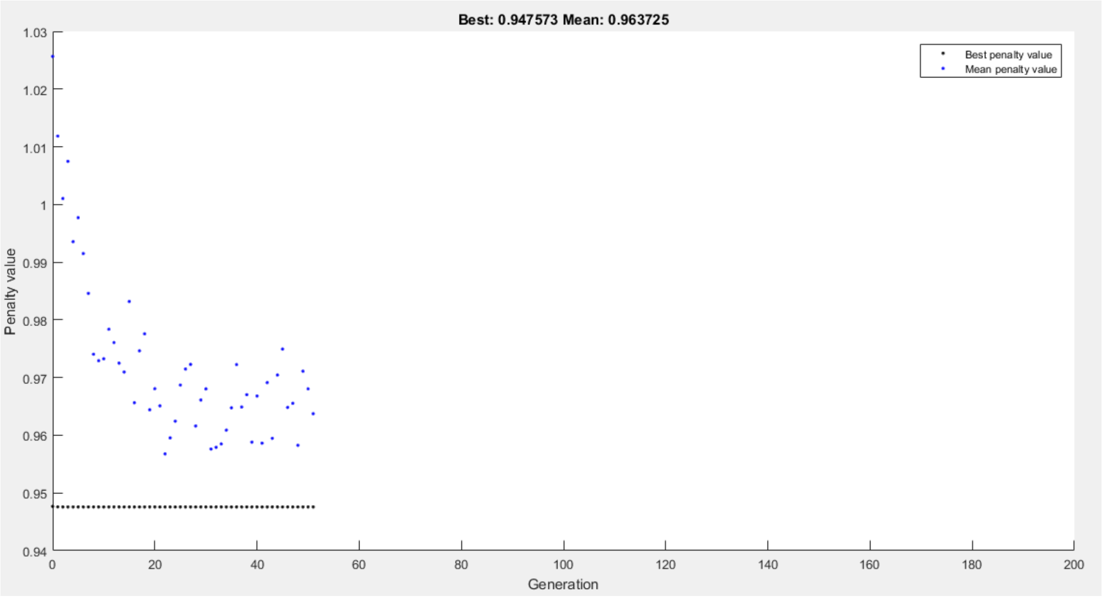

Figure 4.10 The convergence performance for industrial case 4

Figure 4.10 shows the fitness value computed by MIOGA in MATLAB. The optimization was run by installing a 2.4579 kW, 0.473 kW and 0.6295 kW PVDG at bus no. 6,15,25. The simulated results obtained from MATLAB are shown in Table 4.16 below.

Table 4.16 Comparison all load single PVDG and multi PVDG (case 4)

	Method					
	With PVDG (MIOGA) Single DG			With Multi PVDG		
	Residential	Commercial	Industrial	Residential	Commercial	Industrial
Optimal DG size (kW)	1.6493	2.7464	2.4579	1.6493	2.7464	2.4579
				0.456	0.4423	0.473
				0.3767	0.5263	0.6295
Optimal DG location	6	6	6	6	6	6
				14	16	15
				31	25	25

APL index	0.5971	0.544	0.5441	0.4104	0.4551	0.4308
Total P loss (kW)	47.5815	1.8964	7.504	32.4986	1.6149	6.0027
P loss reduction (%)	39.75	39.45	45.51	31.7	14.84	20.01
Total Q loss (kVar)	34.1486	1.3988	5.513	22.8209	1.1501	4.2754
Q loss reduction (%)	36.14	33.96	40.82	33.17	17.78	22.45
Minimum voltage (p.u)	0.9549	0.9622	0.9636	0.9755	0.9762	0.9767
Minimum voltage at hours	23	15-16	17	23	15-16	17
Minimum voltage at bus	18	18	18	18	33	33

Table 4.16 shows the comparison of all load model run with single PVDG and multi-PVDG. For residential, optimal DG size for single DG is 1.6493kW located at bus 6. After the RDN run with multi-DG, the optimal DG size have 3 size which is 1.6493kW, 0.456kW and 0.3767kW and located at bus 6,14,31. For commercial, if single PVDG install, the optimal size of DG is 2.7464kW located at bus 6. While install multi-DG, the size of DG is 2.7464kW locate at bus 6, 0.4423kW locate at bus 16 and 0.5263kW locate at bus 25. After that, the size of DG for industrial is 2.4579kW locate at bus 6. The size for multi-DG industrial is 2.4579kW, 0.473kW and 0.6295kW. All of them located at bus 6,15,25. The power loss for residential load also show the reduction. The real power loss reduces 31.7% from single DG to multi-DG. Besides that, the power loss of commercial load is reduced from 1.8964kW to 1.6149kW after multi-DG installation. For industrial, the power loss is decrease 20.01% after RDN run with multi-DG. Furthermore, the minimum voltage for all load show more improvement when it run with multi-DG compare with single PVDG. As revealed by the residential load, when install multi-DG voltage is 0.9755 p.u compare with single

DG 0.9549 p.u. It is happened during hours 23. Next, the voltage profile for commercial also show improvement and it change from 0.9622 p.u to 0.9762 p.u after multi DG installation. It is occurring at hour 15-16. Lastly, the voltage profile for also show a huge improvement after multi-DG installation which it increase from 0.9636 p.u to 0.9767 p.u. The minimum voltage also occurs at hour 17 although RDN install with single PVDG or multi-DG.

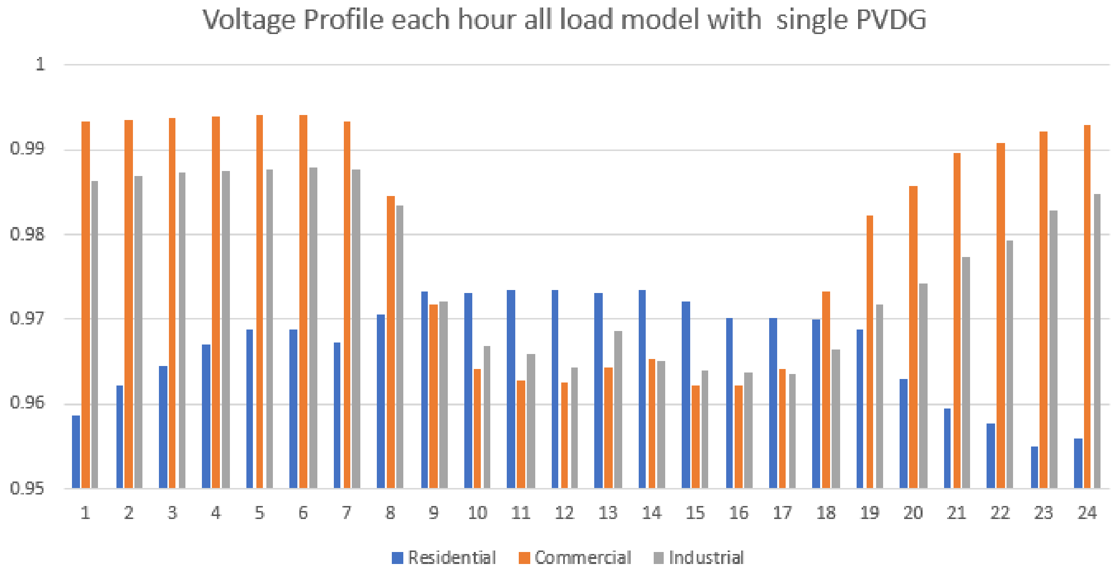

Figure 4.11 Comparison of voltage values case 4 at critical bus single PVDG

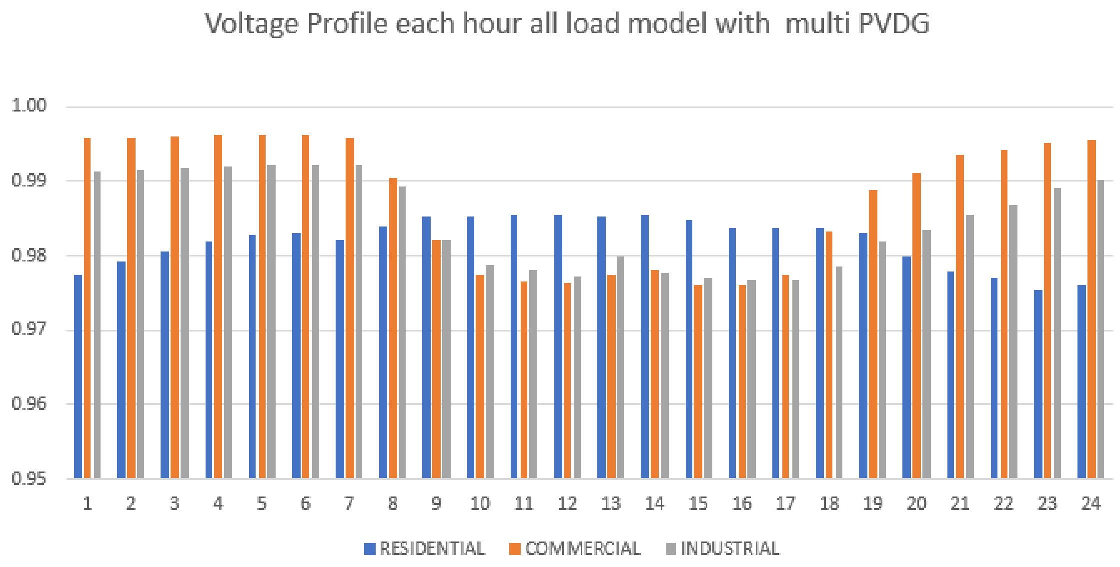

Figure 4.12 Comparison of voltage values case 4 at critical bus multi PVDG

Figure 4.11 and Figure 4.12 illustrates the contrast of the bus voltage magnitude each hour at critical bus between the radial distribution network with single DG and multi-DG. For single DG, the critical bus occurs at same bus which is bus 18 but the critical bus for multi-DG happened at different location. The critical bus for residential load multi-DG is at bus 18 while commercial and industrial load is at bus 33. Therefore, the development of multi-DG helps in reducing total power loss for 33-bus distribution network and at the same time improve the voltage profile.

4.7 Analysis data

The load in the distribution system is an entity which related with the load demand due to the population growth, industrialization, and living standards. For the proper planning of the system, the load variation for each load model as an important parameter must be taken into consideration for the planning of energy work. The optimization results are given in Table 4.17. The load variation on urban area impact taken in the distribution load flows gives an idea to the system operator for planning in advance the improvement of the system and the network design to cater the need.

Table 4.17 Comparison of optimization result for different load model and different number of PVDG

RESULTS	CASE 1	CASE 2	CASE 3	CASE 4		
Total P loss (kW)	47.5815	1.8964	7.504	32.4986	1.6149	6.0027
Total Q loss (kVar)	34.1486	1.3988	5.513	22.8209	1.1501	4.2754
Optimal DG size (kW)	1.6493	2.7464	2.4579	1.6493	2.7464	2.4579
				0.456	0.4423	0.473
				0.3767	0.5263	0.6295
Optimal DG location	6	6	6	6	6	6
				14	16	15
				31	25	25
Minimum voltage (p.u)	0.9549	0.9622	0.9636	0.9755	0.9762	0.9767
Minimum voltage at hours	23	15-16	17	23	15-16	17
Minimum voltage at bus	18	18	18	18	33	33

Every load model has their own total power loss because this investigation is considering time varying for each load model. Consideration time varying load model and number of DG, the power losses are decrease compared to case with no installation of PVDG. According to Table 4.17, it can say that different loading levels of the system for each load model have no effect on the optimal location and only optimal size of PVDG units is changed single DG. But for multi-PVDG (3 DG) installation, the size of first PVDG is maintain with addition of second and third PVDG. After that, there are also 3 optimal locations of PVDG after considering 3 DG installation. The optimal location is important for distribution network in their planning by integrating dispatchable DG units with a wide range of power generation in this location, guarantee the optimal operation of the system. Among the other cases, case 4 (commercial) has the largest DG with sizing of 2.7464 kW, 0.4423 kW and 0.5263 kW at bus 6,16,25.

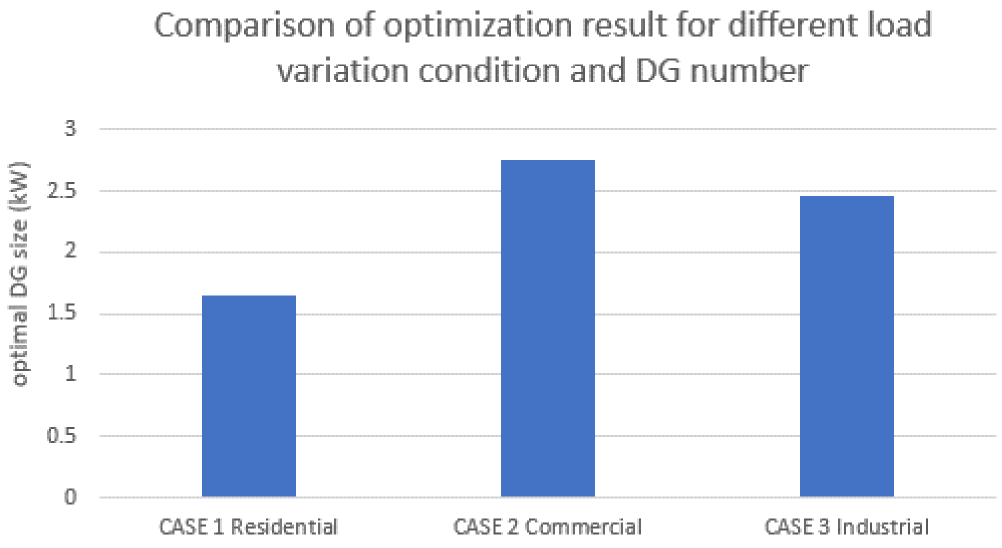

Figure 4.13 DG size comparison for different condition case 1-3

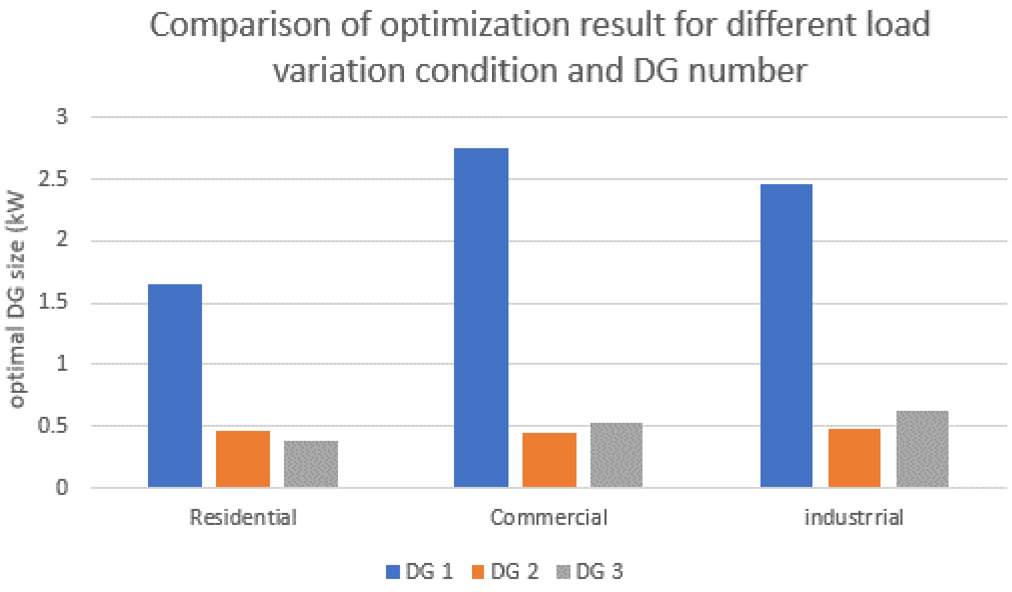

Figure 4.14 DG size comparison for different condition case 4

Table 4.18 Impact of PVDG on total power loss reduction for different load variation and different number of PVDG

DETAILS	RESIDENTIAL		COMMERCIAL		INDUSTRIAL	
	Ploss	Qloss	Ploss	Qloss	Ploss	Qloss
Without DG	78.9673	53.4727	3.1321	2.1182	13.7703	9.3157
With Single DG	47.5815	34.1486	1.8964	1.3988	7.504	5.513

With Multi DG	32.4986	22.8209	1.6149	1.1501	6.0027	4.2754
Loss reduction, %	58.85	57.32	48.44	45.7	56.41	54.11

Load variation demand in residential, commercial, and industrial causes the higher real power loss and reactive power loss. After installation of multi PVDG (3 DG) the power loss is reduced. As the Table 4.18, the power reduction is shown, and the highest power reduction is at residential load (case 1 combine case 4 residential). It reduces 58.85% real power loss and reduce 57.32% reactive power loss compared to without PVDG installation.

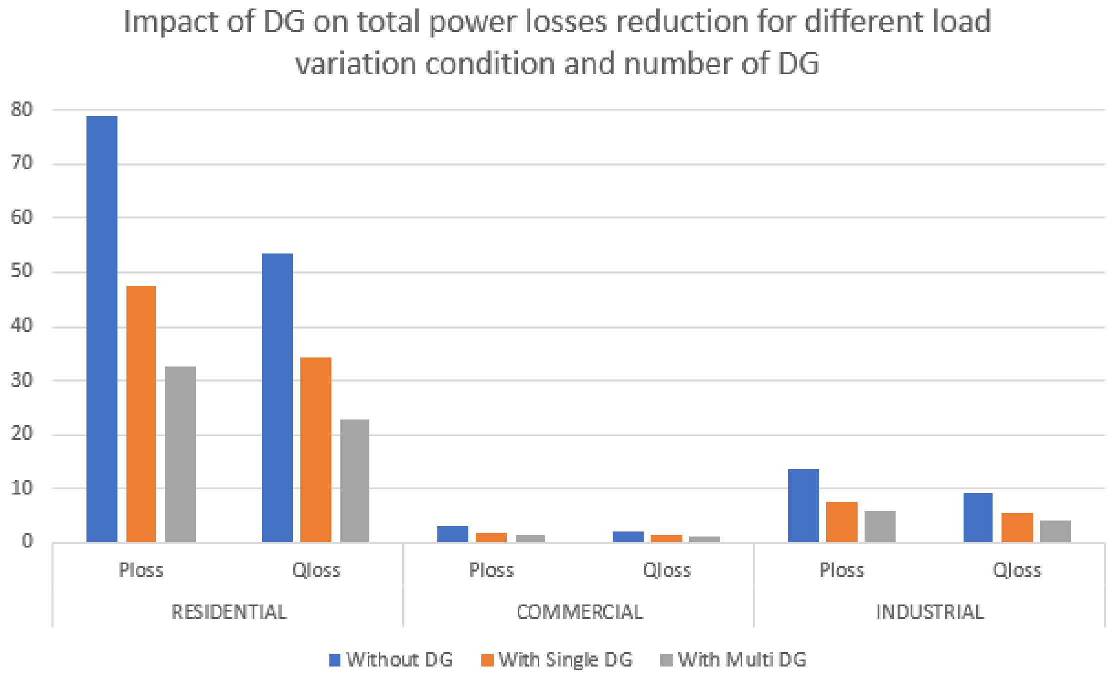

Figure 4.15 Comparison of 2 power loss for different condition

Table 4.19 Impact of PVDG on voltage profile for different load variation and different number of PVDG

DETAILS	RESIDENTIAL	COMMERCIAL	INDUSTRIAL
Without DG	0.9394	0.9345	0.9414
With Single DG	0.9549	0.9622	0.9636
With Multi DG	0.9755	0.9762	0.9767
Voltage Improve, %	3.7	4.27	3.61

Table 4.19 show the comparison of voltage profile for all load model for this investigation which use for case 1-4. This could be proof that with DG placement, there is a slight reduction in the losses due to voltage profile improvement, especially for the lowest voltage magnitudes. The highest voltage improve is at commercial load RDN (combine case 1 and case 4 commercial). It improve 4.27% after the installation of multi-PVDG (3DG) from 0.9762 p.u compare to voltage before PVDG installation which is 0.9345 p.u. Voltage profile for other load model also show voltage increment after installation of multi-PVDG.

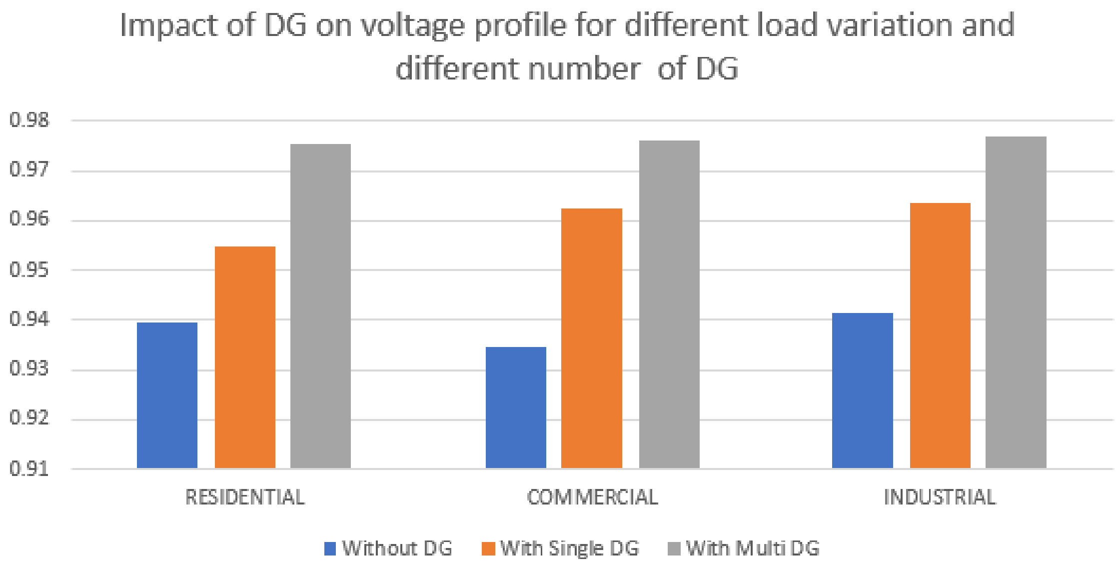

Figure 4.16 Comparison of voltage profile for different condition

4.8 Summary

The findings were obtained by utilising the IEEE 33-bus test system and a combination of two approaches for optimal DG position and size: backward forward sweep power flow and mix integer optimization by genetic algorithm (MIOGA). The issue of penetration was looked into in terms of DG size and placement, as well as actual power losses, reactive power losses, and voltage profile improvement.

CHAPTER 5

CONCLUSION

5.1 Conclusion

The importance of time-varying loads in the efficient design and operation of active distribution networks cannot be overstated. This work presents a new way for determining the ideal size and location of DG. This approach is simple to use and performs well in terms of accuracy. It has been demonstrated that the suggested solution may save a large amount of energy while also improving voltage stability. In this investigation, the installation of a DG unit at a single place at a time was proven to be a viable assumption. However, this research ignores the additional advantages of DG, as well as its economics.

When optimization techniques and load flow solutions are used together, the result is reduced accuracy and a longer execution time. The obtained result is from a method of Mix Integer Optimization by Genetic Algorithm (MIOGA) embedded Backward Forward Sweep Power Flow (BFSPF) established for optimal location and size of DG to help in reducing system power losses and improving voltage profile in radial distribution system network as part of planning in this research work. To execute the simulation, the created technique is applied to the 33-IEEE bus network that was chosen as a test network. The analysis has been done in its entirety. The efficiency of the Backward Forward Sweep Power Flow (BFSPF) technique, particularly in the radial distribution network, has been demonstrated. The Backward Forward Sweep Power Flow (BFSPF) equation may be used to calculate the power loss and the voltage magnitude of each node and hour. The Backward Forward Sweep Power Flow (BFSPF) method was shown to have quick convergence and be adequate for the radial structure.

The performance of the MIOGA (Mix Integer Optimization by Genetic Algorithm) has been demonstrated. The MIOGA approach is used to determine the best DG placement and size. Because of the load variance on their load model, each load model has its own DG size and placement, according to the results. It also demonstrates that multi-PVDG installation has greater benefits than single PVDG installation because it reduces more power losses and achieves the minimal voltage for each load type.

As a result, the research objectives were met, and the integration of the BFSPF and MIOGA combination technique was demonstrated to be an effective method for optimising the location and size of DG in various power networks in order to minimise both real and reactive power losses while delivering excellent voltage profiles.

5.2 Recommendation of future work

Future studies can be conducted based on how well the project fared in this investigation. Here are some ideas to consider:

- More work may be done in the future to adapt AI optimization algorithms to the unpredictability of renewable energy sources.
- Simulating in approach technique takes a long time to iterate, therefore more work has to be done to cut down on this time.
- Engineers in charge of planning should look at the negative consequences of DG and how they might be reduced with proper DG allocation.
- To improve the multi-objective function, other power system issues, such as stability concerns, might be included.

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APPENDIX A
SAMPLE APPENDIX 1

APPENDIX B
SAMPLE APPENDIX 2

APPENDIX C
SAMPLE APPENDIX 3