"Optimal Size & Allocation of Renewable DG in Distribution Systems for Sustainability, Loss Minimization & Vast Voltage Profile Using GA"

A Thesis submitted in partial fulfillment of the requirements for the award of Degree of Bachelor of Science in Electrical and Electronic Engineering.

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March 2022

CERTIFICATION

This is to certify that this thesis entitled "**Optimal Size & Allocation of Renewable DG in Distribution Systems for Sustainability, Loss Minimization & Vast Voltage Profile Using GA"** is done by the following students under my direct supervision and this work has been supported by them in the laboratories of the Department of Electrical and Electronic Engineering under the Faculty of Engineering of Daffodil International University in partial fulfillment of the requirements for the degree of Bachelor of Science in Electrical and Electronic Engineering. The presentation of the work was held on April 2022.

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DECLARATION

This thesis, in whole or in part, has not been submitted to any other institution for awarding degree or certificate.

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The thesis entitled **"Optimal Size & Allocation of Renewable DG in Distribution Systems for Sustainability, Loss Minimization & Vast Voltage Profile Using GA"** submitted by **MD. Ahasanul Islam,** ID: 181-33-4593 and **Md. Zinnah Sarker,** ID: 181-33-4550 has been accepted as satisfactory in partial fulfillment of the requirements for the degree of **Bachelor of Science in Electrical and Electronic Engineering** on April 2022.

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Dedicated to

Our Parents & Teachers

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LIST OF ABBREVIATIONS

IEEE	***Institute of Electrical and Electronics Engineers***
DG	***Distributed Generation***
GA	***Genetic Algorithm***
PSO	***Particle swarm optimization***
LSF	***Least Squares Fitting***
ELF	***Equivalent Lateral Forces***
DER	***Distributed Energy Resources***
PV	***Photovoltaic***
DESCO	***Dhaka Electric Supply Company Limited***
DPDC	***Dhaka Power Distribution Company Limited***
REDB	***Rural Electricity Distribution Backbone***
WZPDCL	***West Zone Power Distribution Company Limited***
SHS	***Solar Home System***
CEI	***Countryside Electrification Infrastructure***
IEC	***International Electrotechnical Commission***
MATLAB	***MATrix LABoratory***
SiO_2	***Silicon Dioxide***
O_3	***Ozone***
ANN	***Artificial Neural Network***
NASA	***National Aeronautics and Space Administration***

LIST OF SYMBLES

P_L	*Power Loss Index*
Pi & Pj	*Real power injection in the bus i & j*
Qi & Qj	*Reactive power injection in the bus i & j*
rij	*Resistance from bus i to j*
$Vi\angle\delta j$	*Voltage at the bus* i^{th}
N	*Number of buses*
I_0	*Diode Saturation Current*
I_L	*Light-generated Current*
I_{sc}	*Short-circuit current*
R_{sh}	*Shunt resistance*
R_s	*Series resistance*
V_{oc}	*Open circuit voltage*
$f(\Psi)$	*Fitness function*
α	*Albert Betz constant*
$\rho(t)$	*Air density*
A	*Swept area*
v(t)	*Wind speed*
β	*Panel Efficiency*
$\mu(t)$	*Solar irradiance*

ACKNOWLEDGEMENT

First and foremost, we express our deepest gratitude to Allah, and then We are thankful to, our supervisor Kanij Ahmad, Lecturer of Faculty of Engineering, for his supervision, guidance, and encouragement during our thesis. His expert guidance on a variety of technical and aesthetic concerns was tremendously beneficial to us.

We must also appreciate Dr. Tawhidul Alam, former Department Head, for his insightful thoughts and recommendations on Distributed Generation modeling and analysis. We'd also want to express our gratitude to

Apart from that, we'd want to express our gratefulness to all of our friends for contributing their knowledge, information, and assistance in making this thesis a success. Thank you also for letting us utilize certain tools and equipment.

Finally, we want to extend our appreciation to Daffodil International University for their cooperation and for encouraging us to continue working on our thesis.

ABSTRACT

Real and reactive power losses occur in radial distribution systems, and voltage profiles are extremely low on buses furthest from slack buses, affecting all loads connected to that network. In this thesis, a strategy for reducing actual and reactive losses in an unstable lower-voltage distribution network is provided, based on DG installation, voltage stability, sustainability, and reliability analysis. Backward/forward analysis is used to determine real and reactive power loss, voltage profiles in each bus of the distribution system. The GA technique is used to determine the optimum size and allocation. Three distinct distribution bus systems have been chosen and justified to apply the above-suggested approach by computing the bus system's line and load data set using heuristic analysis. The optimal solution using GA for determining the optimal production and placement of the DG unit is presented in this thesis. GA is coded in MATLAB Software to identify the best DG solution, and load and line data input for the IEEE-33/14/69 bus systems are provided. The simulation findings demonstrate that implementing an optimal DG size and allocation of IEEE-33/14/69 bus systems may result in significant power loss reduction and a high voltage profile. Optimum DG Capacity Implementation planning strategies have also been presented to lower the cost of the distribution system, enhance stability, and sustainability. To preserve sustainability, renewable energy (solar and wind) has been considered in DG, and the cost of renewable energy in DG has been studied using RETScreen Expert. The achievements of this methodology demonstrate a reduction in power loss, as well as sustainability and high voltage profile.

CHAPTER 1

INTRODUCTION

Power consumption is rising rapidly in all Sectors of the world and the electricity price per unit is also rising due to the shortage of fossil fuels. Distributed Generation (DG) is a heuristic potential way to meet the rapid growth of electricity demand.

Reduced system power loss, increased voltage profile, and increased dependability are just a few of the benefits of DG installation. DG provides low operating costs and is flexible to install in terms of investment and time. Also, renewable energy-based DGs can play a significant role in the construction sustainable energy infrastructure. Typically, distribution systems are designed to deliver power entirely to consumers. Due to its bi-directional power flow, DG will change the character of a distribution network. If its penetration level is too high, there may be a problem of voltage surge due to its reverse energy flow, and improper size and improper placement of DG may result in high power loss in a system that does not have DG. Therefore, the integration of a significant amount of distributed energy resources (DER) can cause operational conflict for a power distribution network.

One approach for considerable loss reduction is to include DG power into the distribution system. Due to the liberalization of power markets, the limits on constructing new transmission and distribution lines, and environmental concerns, this penetration has increased in recent years. For DG applications, there are both conventional and non-conventional technologies. Internal combustion engines, combined cycles, combustion turbines, and micro-turbines are the most common conventional technology. Non-conventional technologies, often known as renewable technologies, employ sun and wind energy to create electricity. Renewable technologies have the benefit of being a free and sustainable source of energy that also removes harmful pollutants.

Consequently, to ensure the reliable, stable, and efficient operation of a power distribution system, DG planning is necessary.

1.1 Background Study

1.1.1 Power Distribution System

The elements of an electric power system between the sub-transmission structure and the customers' service switches are known as power distribution systems. Distribution substations, main distribution feeders, distribution transformers, secondary circuits, including consumer services; and suitable protection and control devices are all included.

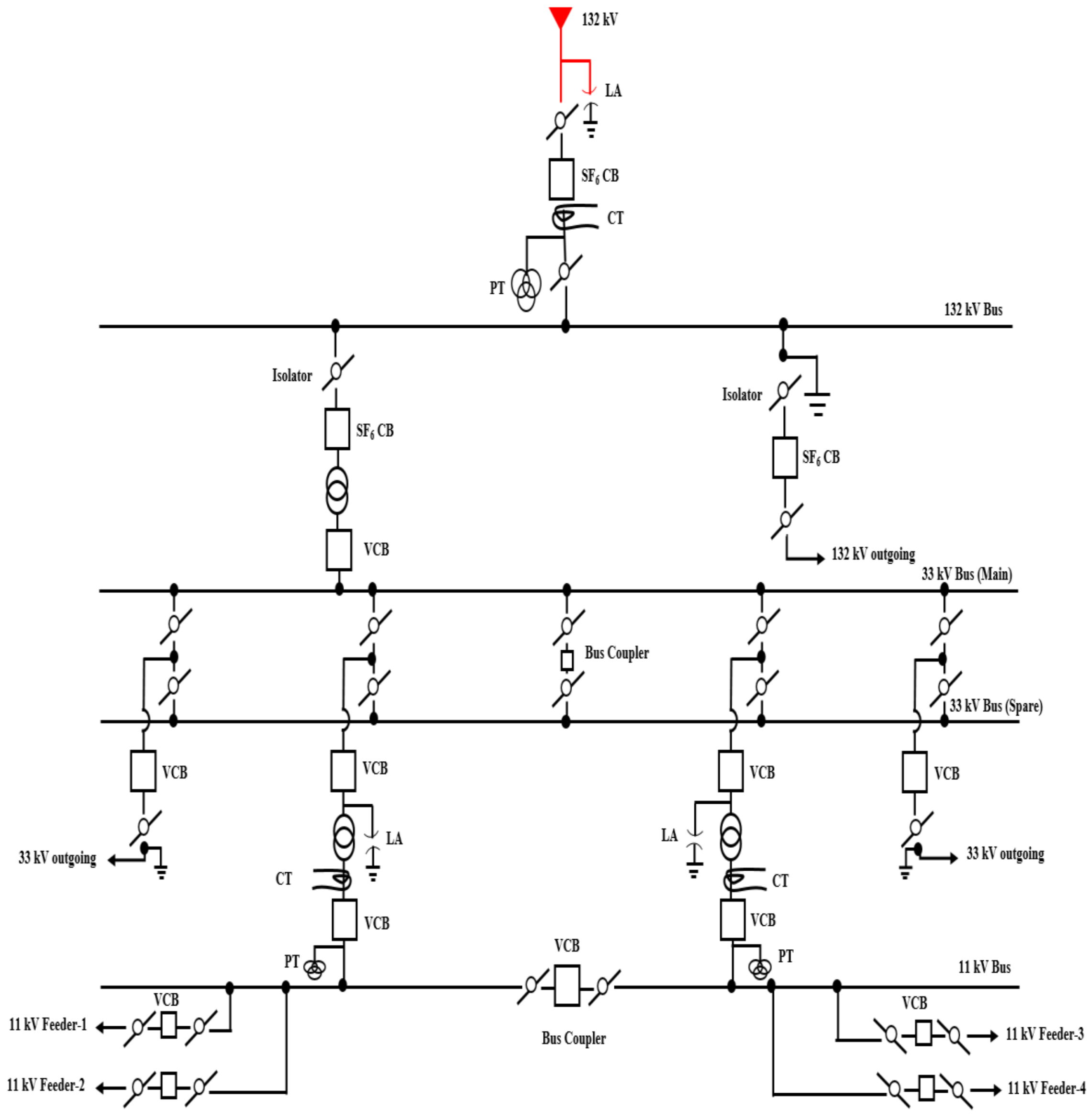

Figure 1.1: 132kV Grid to 11kV Feeder Single Line Diagram

Classification of Power Distribution System:

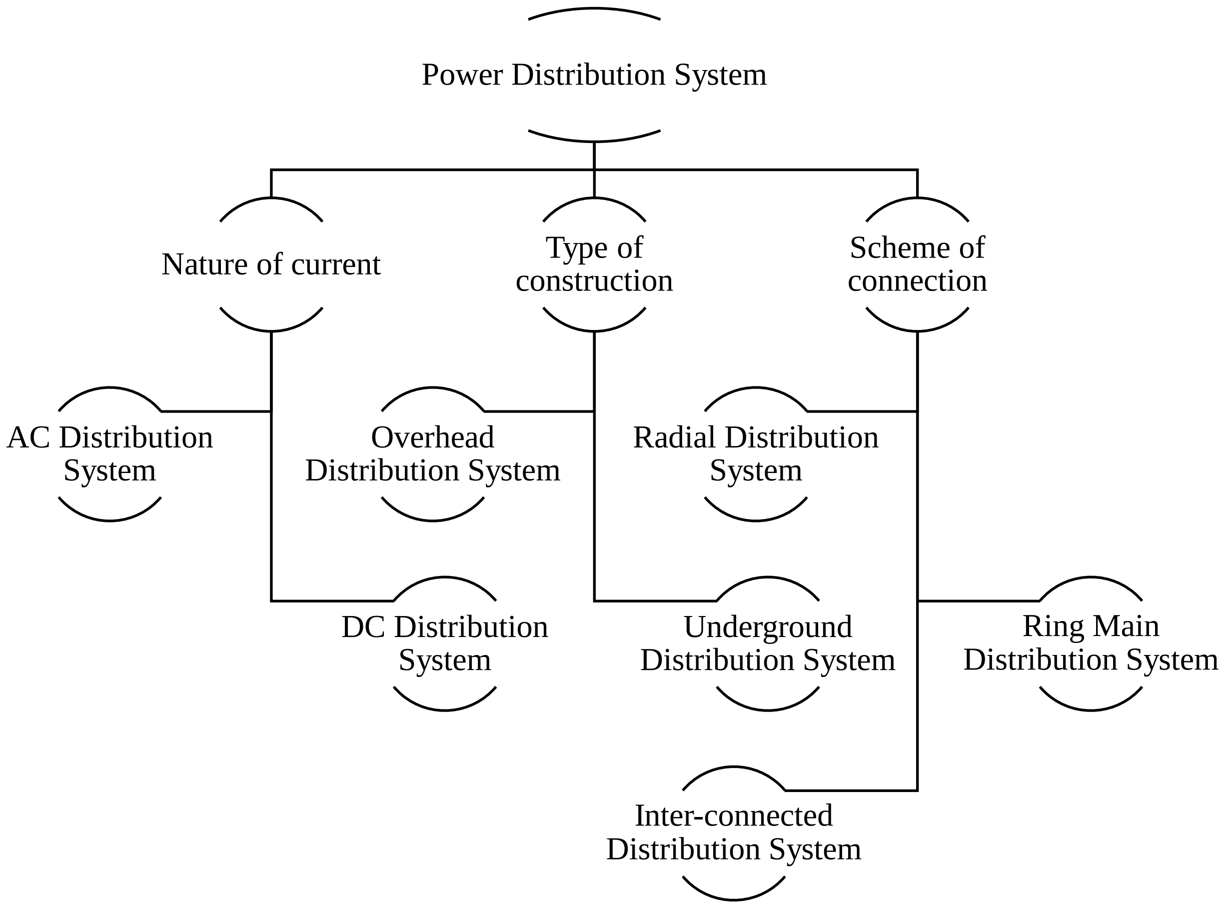

Figure 1.2: Classification of Power Distribution System

AC Power Distribution System:

The AC kind of power is almost entirely produced, transferred, and distributed. With an AC step-up transformer, electricity may be sent across long distances. However, because of the non-changing magnetic flux of DC power, the transformer does not operate.

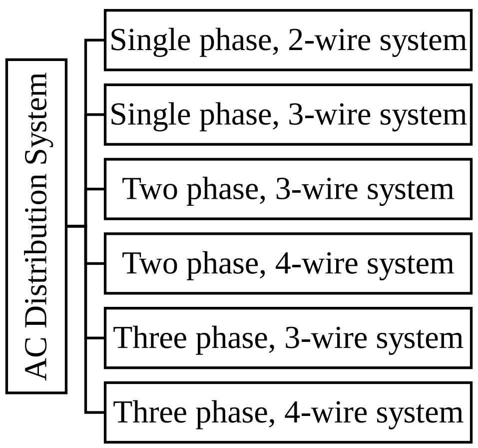

Figure 1.3: Classification of AC Distribution System

Radial Distribution System:

Each customers has a supply source in a radial system, which is structured like a tree. Multiple sources of supply operate in parallel in a network system. For concentrated loads, a spot network is utilized. Emergency connections are common in radial systems, allowing the system to be adjusted in the event of mistakes or issues with scheduled maintenance. This may be accomplished by disconnecting a particular portion from the grid by opening and shutting switches.

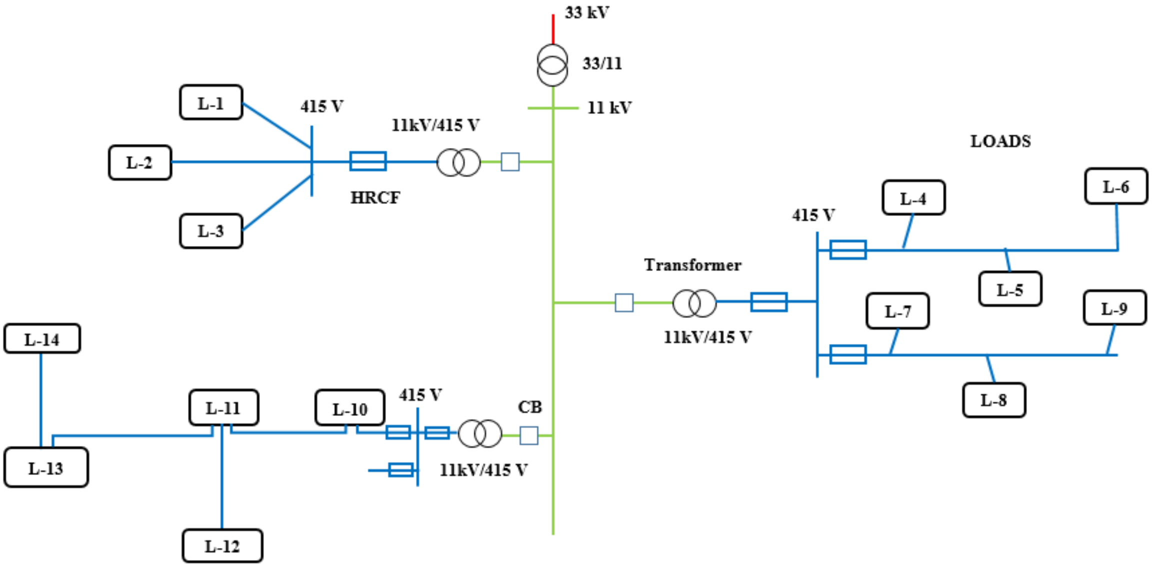

Figure 1.4: Radial Distribution System

Parallel Feeders Distribution System:

A parallel feeder distribution system is a distribution system that is designed to add a parallel feeder to a radial distribution system. It is crucial in maintaining an uninterrupted power supply.

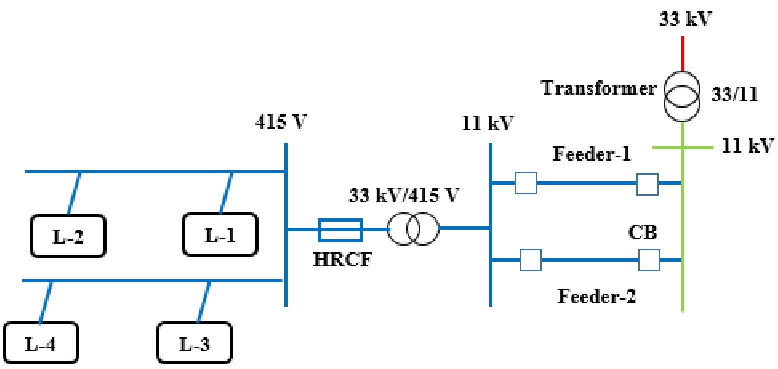

Figure 1.5: Parallel Feeders Distribution System

Ring Main Distribution System:

In Ring Main Distribution System, Each distribution transformer is supplied by two feeders that go in opposite directions. The feeders in this system create a loop that begins at the substation bus-bars, travels across the load area feeding distribution transformers, and then returns to the bus bars at the substation. Because each distribution transformer is supplied by two feeders, the system is very stable & secure. This implies that in the case of a malfunction in any portion of the feeder, the supply will be maintained in an alternate way.

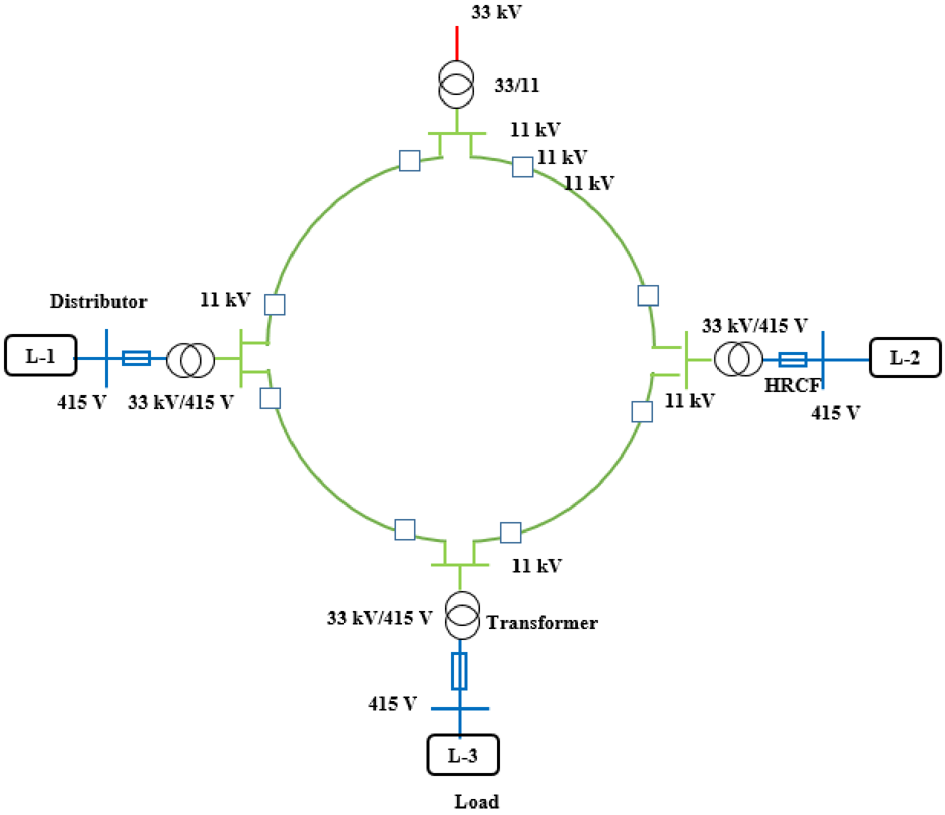

Figure 1.6: Ring Main Distribution System

Inter-connected Distribution System:

An interconnected distribution system is one in which a ring main feeder is powered by two or more substations or generating units. In the case of a transmission breakdown, this technology provides dependability. Any region supplied by one generating station or substation may be fed from the other generating station or substation during peak demand hours to meet greater demand power needs.

1.1.2 Distributed Generation

Distributed generation is a fragmented or one-site generation that produces a little amount of electrical energy for the end-user to enhance the energy efficiency, helps reduce carbon pollution, improve resilience and invest in a new transmission.

As economic development has surpassed the expansion of power supply in some areas of the country and in some areas where power supply is limited, it is important to encourage local alternatives for power transmission.

Furthermore, our country's electricity is generated by existing centralized sources that carry significant quantities of energy across great distances. 11.11% of the energy produced in our country is lost due to the transmission and distribution process and most of it is transmitted over long distances. Creating a new transmission line can be a costly sighting problem. Also when the grid goes down the target can remain without electricity. Where small power systems are installed and distributed generation can solve this problem. Power Systems can be transferred from any military base to Borough College campus to large industrial factory residential areas. When an electrical load is linked to a low-voltage distribution network, distributed generation may assist in supplying clean, dependable energy to prospective consumers. It can really reduce the loss of transmission and distribution lines. Certain renewable energy sources, such as solar and wind power, are examples of distributed generating resources.

Generations distributed in essential sectors include small wind turbines, large solar panels on rooftops, natural gas powered small cell emergency backup generators. District heating systems, solar PV panels, wind turbines, and hydroelectricity are examples of commercial and industrial generators. [5]

Conservational impression of distributed generation:

1. Distributed generation arrangements necessitate a specific space most distributed generating techniques may be inconvenient or generate land-use difficulties since they are placed near to the end-user.

2. DG technologies that use combustion, particularly fossil fuels, produce the same pollution levels as huge fossil fuel-powered power plants. These innovations might be located near densely inhabited regions.

3. Certain decentralized generating methods, such as lightning, biogas combustion, and combined thermal power, may need water to create or cool vapor, and their pollutants may be harmful to the environment.

4. Due to scale efficiency, combustion-based power plants may be less efficient than generators.
5. Production distributed using local power sources can be contagious in the power supply system and line loss may occur during distribution.
6. When DG technologies are changed or withdrawn, they may have a detrimental impact on the environment.

Reliable efficiency:

1. Distributed generation is the first step. When centrifugal power plants send energy across great distances, part of it is wasted, and this is no different. With distributed generation, we're getting close to utilizing electricity generated by generators. As a result, there is less wastage.
2. The DG acts as a backup of the grid and as an emergency resource for public services during natural disasters.
3. By generating a sustainable power source, the DG system can reduce the maximum time demand of a particular area and reduce traffic congestion on the main grid.
4. Since the power to distribute comes from renewable sources, it reduces the cost of using good renewable energy for the environment.
5. Peak Power Saving, Distributed Generation during Peak Demand Period contributes to the supply of electricity during this high demand period. It can also be associated with high demand for load shedding and transmission line congestion and solve such problems.
6. Because DG placement raises the voltage level, it aids in the resolution of power quality issues such as voltage instability. The issue may also be solved by using the power factor.
7. DG Stand can work in a mode that gives customers the option to connect to the grid. This results in 7% reduction in grid losses and can save 12-15% on network costs.
8. Efficient use of cheaper fuels Installing distributed generation units increases the chances of using cheaper fuels such as: Landfill gas burning when distribution generation facilities are installed near landfills.

1.1.3 IEEE Bus System

Here three different bus systems illustrated for analysis DG optimization & allocation.

IEEE-33 Bus:

IEEE 33-bus radial distribution system consisting of 33 buses and 32 lines and has a voltage of 12.66kV, load size 3.715MW, and 2.3MVar. Tie switches are 33, 34, 35, 36, 37. [2]

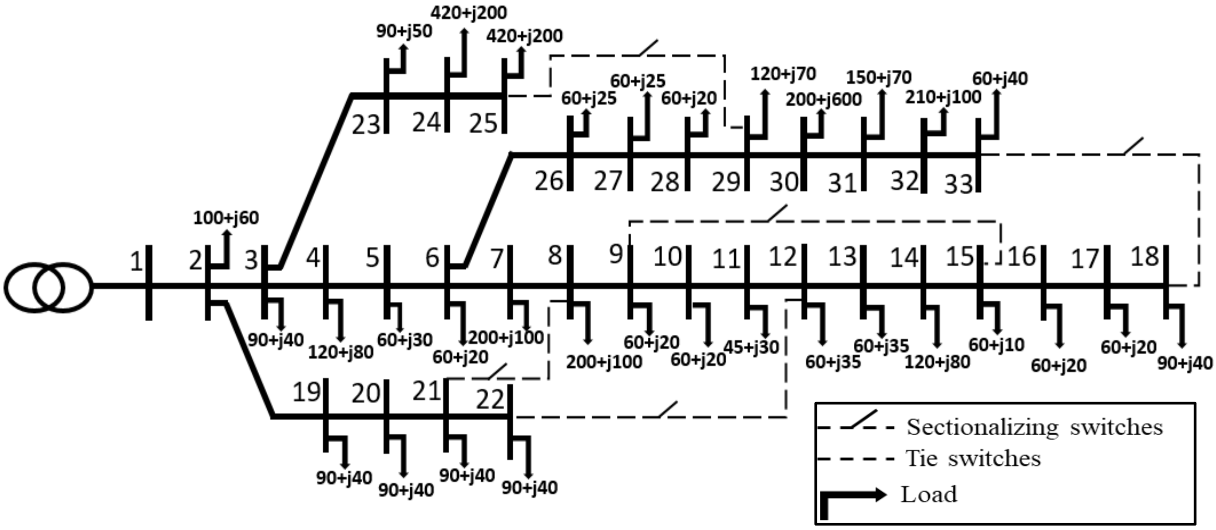

Figure 1.7: IEEE-33 Bus System

IEEE-14 Bus:

IEEE 14 bus system consisting 14 buses, 5 generators, and 11 loads. [12]

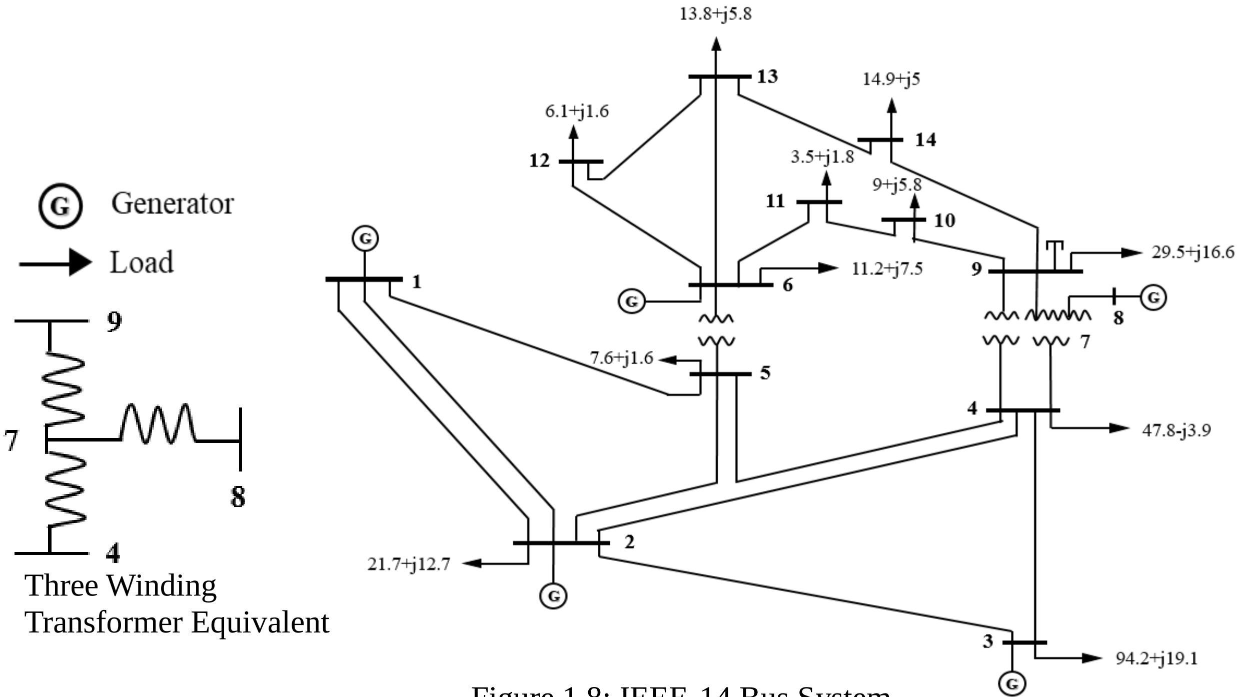

Figure 1.8: IEEE-14 Bus System

IEEE-69 Bus:
Each branch of the IEEE 69 bus test system has 69 nodes, 5 looping lines, 7 lateral feeders, and edges. With a system voltage of 12.66 KV, the total connected load in this system is 3802.19 kW and 2694.60 KVAr. [2]

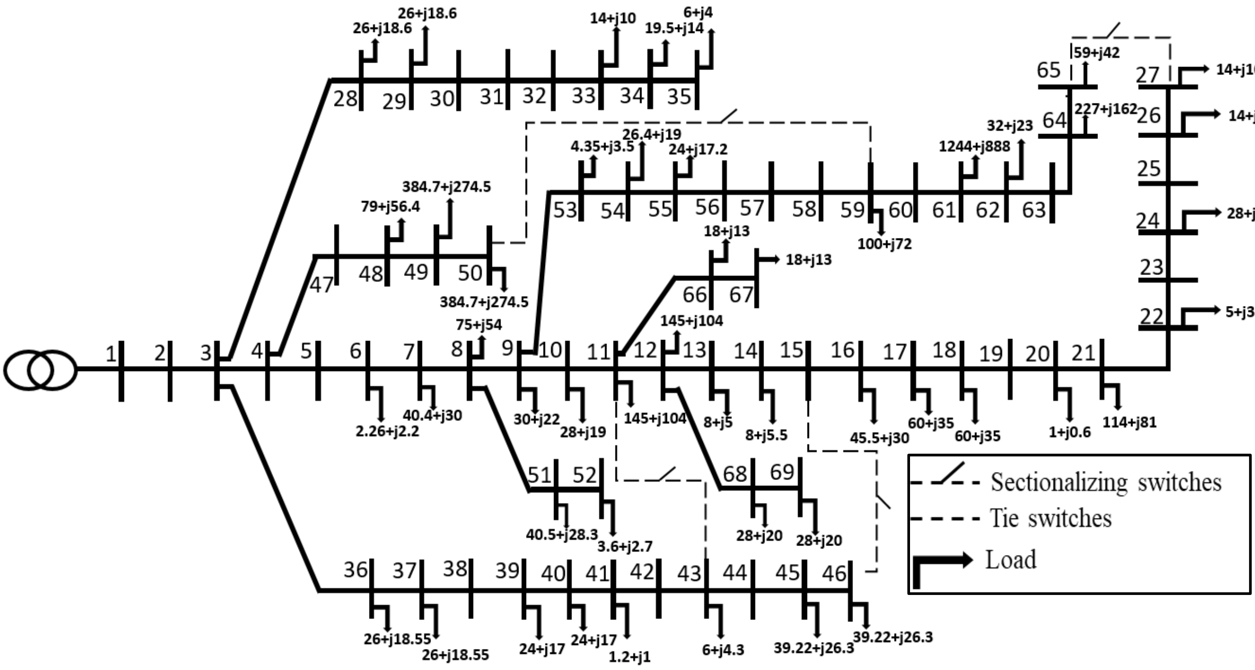

Figure 1.9: IEEE-69 Bus System

1.1.4 Power System of Bangladesh

Power system is an integrated network that connects equipment and materials related to power generation, transmission and supply.

The Power Development Board of Bangladesh generates 75% of the electricity supplied to the customers. The remaining 25% of electricity is created by mutually owned and hired power plants by domestic and foreign companies. Responsibility for distribution of electricity across the country rests with a few government agencies or companies based on their respective areas. These organizations are BUB, Rural Power Development Board, DPDC, DESCO and WZPDCL.

Bangladesh's industrial power sector has a nationwide grid with a cumulative installed capacity of 20000 MW and a total installed capacity of 21419 MW (September 2019).

The power division of Bangladesh is separated into two regions, the eastern region and the western region. The eastern part has adequate hydropower and gas fields, so the lion's share of electricity comes from this region. Alternatively, the 250 MW power plant in the west has a huge role to play in the field of power as well as the gas field in the east. Normally there is a power deficit area in the west which has to bring about 500 MW power from the east through 230 kV two east-west interconnection transmission lines.

The fuel mixture used in power plants in Bangladesh is heavily supported by natural gas. The Government of Bangladesh has strategies to growth the use of bring in liquefied natural gas (LNG) due to the reduction of native natural gas fields. Bangladesh's largest energy consumers are the industrial and residential sectors, followed by trade and agriculture. As of 2019, the population was rural 10 crores and 88.85% had electricity.

Overall system leakage, delays in constructing new plants, poor plant productivity, erratic power supply, power theft, blackouts, and a lack of cash for power plant servicing are all issues in Bangladesh's power industry.

LNG Imports:

In recent years, Bangladesh has been taking risks to ingress liquefied natural gas to meet its growing energy demand. In 2018, Maheshkhali is its first floating has installed storage and regasification.

Solar power:

Bangladesh has successfully implemented a large-scale solar home system solar project. Where 5.6 million SHS have been installed nationwide. Renewable energy provides for less than 1% of the entire power generating capacity in the nation. The aim is to grow weighty renewable sources of energy like wind and solar energy to 10% of total energy capacity by 2022, notwithstanding the comparatively high initial costs of building up a renewable energy sector and renewable energy facilities owing to land availability.

In Bangladesh, there are several utility-scale solar PV companies, including Teknaf Solar Park, which has a capacity of 200 megawatts, Sutiakhali Solar Park, which has a capacity of 50 megawatts, and Sunamganj Solar Park, which has a capacity of 32 megawatts. Contraptions of Power and Energy Despite the Bangladeshi government's efforts to attract corporate and international investment, timely revamping of aging power plants and the manufacture of new power plants has been hampered by a lack of funding and appropriate fuel sources. But every year the electricity demand of the consumers is increasing at the rate of 10%. Current power plants are old, dilapidated, have lost production capacity and are almost in trouble. In addition, due to low pressure gas supply, power generation is much less than required.

1.1.5 Different Loss Mechanisms

Power transmission and distribution are divided in plants to two parts

1. Technical loss
2. Non-technical loss

Technical loss:

Technical corrosion to transformers, circuits, transmission line distribution line equipment and transformers causes technological degradation. Unexpected load increase is reflected by increase in technical damage above normal level.

Local Technical loss:

Open circuit loss, corona destruction, and insulator destroy are examples of losses that do not change with current and exist as long as a transformer is active. These losses take the form of heat and sound and persist as long as a transformer is active.

Temporary Technical loss:

The variable loss distributed varies with the measurement of electricity which is currently proportional to the square, such as: long line distribution, impedance loss, damage to voltage line, loss due to contact resistance.

Some of the main causes of technological damage

1. Long line distribution such as: Large scale rural electrification through long 11 KV and LT lines.
2. Insufficient size of conductor in distribution line
3. Apart from the load zone, distribution transformers are installed.
4. One of the simplest disadvantages of feeder phase-current and load balancing distribution systems is the balance of current along the 3 phase circuit. The feeder balances and balances the voltage drop between phases which gives their 3 phase subscribers less imbalance.
5. The effect of the load factor is calculated as the average load in a particular time divided by the greatest load in that period.
6. Sizing and selection of transformers

More other causes of technological loss:

1. The LT system's three phases have unbalanced load distribution, resulting in large null currents.

2. Line overloading and loss of power

3. Abnormal operating conditions where power and distributor hall transformers are operated

4. In rural areas agricultural pumping, cooling air conditioners, equipment is used for low-quality loads in urban areas.

Non-technical loss:

Measurements, malfunctioning meters, invoicing at the expense of customers' energy expenditures, lack of administration, financial limits, a limitless supply of energy, and the risk of electricity theft are all examples of non-technical faults.

The main reason:

1. Electricity theft
2. Meter error
3. Small load without meter
4. Error of meter reading
5. Billing problem
6. Transfer the line directly from the feeder to the industrial customer
7. Old conductor or its installation.

1.1.6 DG of Different Countries

India: DG implementation at the distributed generation rural level is the best option compared to GE, many challenges and shortcomings in the Indian energy sector. In developing countries such as Nepal, China, Cambodia and the Philippines, the DG alternative to rural electrification has been successful. Large scale implementation in India considering the availability of a lot of renewable energy in the state. DGs can be based on traditional and renewable energy sources that allow local power generation using local resources that are less dependent on external resources. The goal is to electrify about 1.15 lakh villages without electricity and 2.34 lakh Billow Poofy Line (BPL) households under the Twelfth Five Year

Plan. Develop a Rural Electricity Distribution Backbone (REDB) with at minimum one 33 / 11kV or 66 / 11kV substation and a Countryside Electrification Infrastructure (CEI) with at least one transformer for each block. DG capability largely depends on the type of user and usage. The efficiency of DG depends on the equipment used, either in the form of alternating current (AC) or direct current (DC). DC solar is made by photovoltaic and fuel cells which are suitable for DC load. The DC generated from the DG system can be converted to AC for AC load and grid supply using the Power Electronics interface. . The division of DG projects also depends on the energy source used for power generation. The length of the DG power output varies greatly depending on the size, form and application of the DG. This can take a long time for normal load applications, only a short time for maximum load and for an unreliable supply.

China: Distributed production is gaining traction in China because to its efficacy and efficiency in increasing the use of renewable energy. China is a nation undergoing fast industrialization and urbanization, with limited energy supplies and environmental degradation. Over the past decade, great efforts have been prepared to increase the distribution of distributed generation in China. China's biggest inspiration is its rapidly growing, diverse demand for energy and the difficulty of making the most of renewable energy in an efficient way. Verification of Microgrid Advanced Technology, Demonstrating Microgrid Capabilities in Safe and Sustainable Operations, Acceptable Power Quality Supply. 100kW solar photovoltaic (PV) and 1.5-MW CCHP.
The East Inner Mongolia Rural Microgrid project uses 110 kW PV, 50 kW wind power and 50-kW lithium-ion ferrous phosphate batteries. To supply electricity at relatively low cost, as opposed to under ground cable or diesel supply, 1 MW wind power, 660 kW PV, a 1,700-kW diesel generator, a. 4,000-kWh battery and 1MW × 15s super-capacitor.

The present operating method of microgrid in China may be split into three types, according to the microgrid and distribution generation investment operation body: unified purchase and sale mode, self-generation-self-use mode, and contract power management mode. In China, there are two main modes of microgrid operation: unified purchase and sale, in which distributed generation output is sold entirely to utilities, and self-generation-self-use, in which distributed generation output is desired by owners and surplus is sold to utilities.

Microgrid growth is aided by the advent of a new idea, energy connectivity, which is seen as a potential development component of smart grids. The microgrid is the fundamental unit of energy in the Internet in terms of energy connections. China's future energy Internet resembles a smart creature: the ultra-high voltage power transmission infrastructure serves as the aorta, and microgrids serve as vital blood capillaries to enable effective green energy production. use at the end of the grid. Internet and In the future, information technology may be used to build renewable energy microgrids, allowing for multi-party involvement in the electrical market and intelligent matching of power output and usage, resulting in a new platform for more efficient and sustainable energy use.

Russia:

Russian Distributed Power Generation was created in 2010 as a non-profit corporation. It brings together small-scale energy and high-tech businesses that operate in connected fields. The organization was formed to bring together the distributed power production industry and to assist in the coordination of collaborative efforts to undertake new energy projects in the Russian and international markets. Currently, the group has completed 54 power projects totaling 300 MW in capacity. The International Award "Distributed Power Generation - Great Achievements," which is granted yearly, is the Distributed Power Generation Association's primary public initiative. The prize, which was established in 2013, recognizes the most well-executed small-scale distribution and alternative energy initiatives.

Philippines: With the use of equipment placed on their own premises, consumers may create up to 100 kilowatts of power from sources such as solar, wind, and biomass. They may sell the excess power supply to their distribution utility provider if they generate more than they cost.

1.2 Problem Statement

The fundamental issue with a radial distribution system is a significant power loss and voltage drop, which impacts all loads connected to it.

Various nations continue to use radial distribution networks and non-renewable power plants, resulting in environmental damage due to non-renewable generating fuel shortages and excessive carbon dioxide emissions. The price of fossil fuel-based power plants per unit of energy has been rising. Despite the fact that the demand for electricity is growing by the day, conventional power plants will become ineffective due to a lack of fuel. High voltage profiles and non-interruptible power supply are not achievable at the consumer end in radial distribution systems.

In order to implement a renewable energy plant, numerous elements must be considered. Solar irradiance, Plant Area, and Climate change for Solar Plants are only a few examples. On the other hand, Wind Speed, Swift Area, and Wind Direction for Wind Turbine.

1.3 Thesis Objectives

- Modeling and implementation of DG by Genetic Algorithm.
- Heuristic analysis and optimal solution of DG size and allocation.
- Load flow analysis for IEEE-33/14/69 bus systems.
- Backward/Forward analysis to find out the power loss of each bus.
- Problem formulation of radial distribution systems.
- Solar and wind data analysis by using MATLAB.
- PV module circuit simulation by MATLAB Simulink.
- Selection of solar Areas by Google Earth.
- Cost Analysis of renewable DG by RETScreen Expert.

1.4 Thesis Organization

This thesis is organized into six chapters, with a short synopsis of each part provided below.

The introduction, background research, literature review, Problem Statement, Thesis Objectives, and Thesis Organization are all included in Chapter 1.

This chapter focuses on the particular purpose of this study by providing a short literature review on Distributed Generation, IEEE-33/14/69 bus systems, the power system of Bangladesh, Loss Mechanisms connected to Power Supply, and DG of other nations, with their benefits, demerits, and limitations.

In Chapter 2, the proposed methodology is presented Load Flow Analysis, Backward/Forward Analysis, Genetic Algorithms, and other topics are covered in this section. All data collection and acquisition is presented in tabular form in Chapter 3.
The implementation of DG and the best solution of DG size, allocation, Voltage Profile graph, Comparison, and other topics are discussed in Chapter 4. The use of renewable energy in DG is presented in Chapter 5 via the use of an analytical model. PV cells, wind turbines, data collecting, modeling, and other topics are covered in this section. The cost analysis of renewable energy in DG is shown in Chapter 6.

Chapter 7 concludes with a conclusion and the scope of future study activity. Appendices are included at the conclusion of the paper to enhance the research and analysis offered here.

CHAPTER 2

LITERATURE OVERVIEW

2.1 Literature Overview

Chandrasekhar Yammani, Sydulu Maheswarapu, Sailajakumari Matam, "Optimal Placement of Multi DGs in Distribution System with Considering the DG Bus Available Limits", proposed genetic algorithm implementation for optimal placement and size of DG. DG Implementation has been tested on the IEEE-38 bus system and a renewable source has been attached to the DG. Tested in a few steps such as Without DG, Only Solar, Only Wind, Solar + Wind, Solar + Wind + Fuel Cell, All 4 DGs. Significant results of Power Loss Reduction have been shown. [1]

In April 2013, Duong Quoc Hung and Nadarajah Mithulananthan, "Multiple Distributed Generator Placement in Primary Distribution Networks for Loss Reduction", several versatile DGs have been installed in the primary distribution network to reduce network losses. Allocation of multiple DG units using IA, LSF, and ELF methods is confirmed here. The IEEE-33/69/17 bus system has been used as analysis. [2]

Mohan Kashyap, Ankit Mittal and Satish Kansal, "Optimal Placement of Distributed Generation Using Genetic Algorithm Approach", Approved placement of DG using GA. Significant results of power loss reduction have been obtained by applying DG in IEEE-33/69 bus system. [3]

Mesut E. Baran, Felix F. Wu, “Network Reconfiguration in Distribution Systems For Loss Reduction and Load Balancing,” A model of loss reduction of distribution system utilizing GWO algorithm has been suggested using Branch-Current to Bus Voltage Metrics and Forward Sweep technique using IEEE 33/69 bus system. [4]

In November 2012, Adnan Anwar, "Distributed Generation Planning for loss and cost minimisation in Power Distribution Systems", School of Engineering and Information Technology, the University of New South Wales, DG planning has been done to minimize loss and cost. Swarm Intelligence has been used to minimize power loss and cost minimization to plan for energy loss reduction. [5]

Mostafa Sedighizadeh, Marzieh Dakhem, Mohammad Sarvi, Hadi Hosseini Kordkheili, "Optimal reconfiguration and capacitor placement for power loss reduction of distribution system using improved binary particle swarm optimization", Reconfiguration and capacitor placement utilizing improved BPSO has yielded the best option for reducing the distribution system's power loss. [7]

G.Srinivasan, Dr. S.Visalakshi, “Application of AGPSO for Power loss minimization in Radial Distribution Network via DG units, Capacitors and NR”, Power Loss Minimization Using DG, Capacitor, and NR in Radial Distribution System has been presented by AGPSO. [8]

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CHAPTER 3

METHODOLOGY

3.1 Introduction

Our proposed methodology is Distributed Generation which is a Small power plant or decentralized Generation. Some algorithms need to be used for DG implementation. Here we will do load flow analysis to find out the power of the bus and use the backward forward analysis method to find out the power losses. And finally selected the genetic algorithm to find out the DG's size, Allocation, Voltage profile & optimum solution. I have done all the calculations through MATLAB software, the result of which will be given in the next chapter.

3.1.1 Power Losses

$$P_L = \sum_{i=1}^{N}\sum_{i=1}^{N} \alpha_{ij}\left(P_iP_j + Q_iQ_j\right) + \beta_{ij}(Q_iP_j + P_iQ_j) \tag{3.1}$$

Where,

$$\alpha_{ij} = \frac{r_{ij}\cos(\delta_i - \delta_j}{V_iV_j}, \quad \beta_{ij} = \frac{r_{ij}\, sin(\delta_i - \delta_j)}{V_iV_j}$$

P_L= Power Loss Index

P_i & P_j = Real power injection in the bus i & j

Q_i & Q_j = Reactive power injection in the bus i & j

r_{ij} = Resistance from bus i to j

$V_i\angle\delta_j$ = Voltage at the bus i^{th}

N = Number of buses

3.1.2 Problem Formulation

Fundamental focus is to reduction of the power loss (*P_{loss}*) with increasing voltage profile. The proposed Genetic Algorithm technique will be exploited to compute the power loss and determine the optimal sizing & allocation of DG. The objective function is mathematically expressed as follows: [3]

$$Min\Psi(\Upsilon_p) = \left(\sum_{i}^{N_i} P_{loss}^{with\ DG}\right) \tag{3.2}$$

$$Min\Psi(\Upsilon_p) = \left(\frac{\sum_{i}^{N_i} P_{loss}^{with\ DG}}{\sum_{i}^{N_i} P_{loss}^{without\ DG}}\right) \tag{3.3}$$

Voltage limits at all nodes:

$$v^{min} \leq v_i \leq v^{max} \tag{3.4}$$

Thermal limits:

$$I_{L\_i} \leq I_{L\_\max\_i} \tag{3.5}$$

DG power limits:

$$P_{DG}^{min} \leq P_{DG_i} \leq P_{DG}^{max} \tag{3.6}$$

Fitness function f(Ψ) is weighed as follows:

$$f(\Psi)_i = \frac{\Psi(\Upsilon_P)_i}{\sum \Psi(\Upsilon_P)_i} \tag{3.7}$$

Load Current:

$$I_j^{(k)} = \left(\frac{PLj+jQLj}{V_j^{(K-1)}}\right)* \quad \text{for } j=2,3,4\ldots\ldots\ldots..N \tag{3.8}$$

Voltage Profile Index:

$$IVD = \max_{i=2}^{n} \left(\frac{|V_1| - |V_i|}{V_1}\right) \tag{3.9}$$

Real & Reactive loss indices:

$$ILP = \left(\frac{Total\ P_{loss}DG}{Total\ P_{loss}Beyond\ DG}\right) \tag{3.10}$$

$$ILQ = \left(\frac{Total\ Q_{loss}DG}{Total\ Q_{loss}Beyond\ DG}\right) \tag{3.11}$$

3.2 Load Flow Analysis

The most significant and necessary way to investigate issues in power system operation and planning is load flow analysis. Load flow analysis solves the stable operating state with node voltages and branch power flow in the power system based on a certain producing state and transmission network structure. Without taking into account system transient events, load flow analysis may offer a balanced steady-state operating condition for the power system. As a result, the mathematical model for the issue of load flow is a nonlinear algebraic equivalence system with no differential equations.

The load flow issue is a set of nonlinear algebraic equations that must be solved mathematically. Its solution almost always requires some kind of iteration.

The Gauss–Seidel iterative approach based on a nodal admittance matrix was the most extensively utilized method. The impedance approach enhanced convergence and resolved several load flow issues that the admittance method couldn't. The impedance method's biggest downside is its high memory and computation requirements.

The load flow calculation approach has evolved in numerous ways since the 1970s. The quick decoupled approach, commonly known as the P-Q decoupled method, is the most effective among them. This approach is simpler and more efficient algorithmically than the Newton method, and hence more common in many situations.

Methods:

- Gauss-iterative Method
- Gauss-Seidel Method
- Newton Raphson
- Fast De-Coupled Method

3.3 Backward/Forward Sweep Analysis

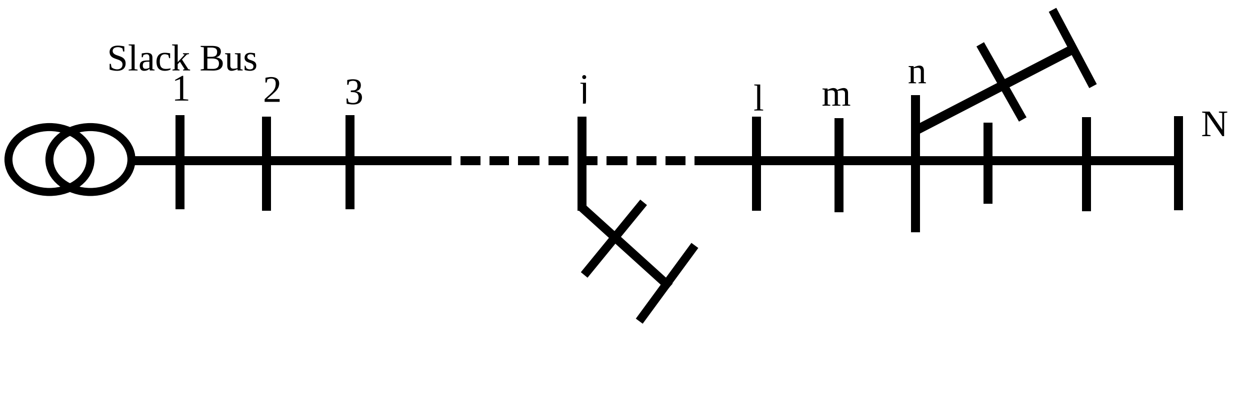


Figure 3.1: Radial Distribution Network

Step-1: Initialization of voltages,

$V_j(0) = V_s\angle 0°$ for j=2,3,4………..N

Step-2: Iteration count initialization K=1.

Step-3: Load Current Computation,

$I_j(k) = \left(\frac{P_{Lj}+jQ_{Lj}}{V_j(K-1)}\right)^*$ for j=2,3,4………..N

Step-4: Backward Sweep,

$I_{mn}(K) = I_n(K) + \sum$ of all the currents of branches emanated from bus n

Step-5: Forward Sweep,

$V_n(K) = V_m(K) - Z_{mn} I_{mn}(K)$ for j=2,3,4………..N

Step-6: $e_j(K) = | V_j(K) - V_j(K-1) |$ for j=2,3,4………..N

Step-7: $e_{max}(K) = \max(e_2(k), e_3(k), e_4(k) \ldots\ldots e_n(k))$

Step-8: If $e_{max}(K) \le \varepsilon$ (tolerance)

else update iteration count K=K+1 & go to step-3.

3.4 Genetic Algorithm

A genetic algorithm is an optimization heuristic based on Charles Darwin's natural selection hypothesis. This algorithm simulates natural selection, in which the fittest individuals are chosen for reproducing to create the future generation.

The genetic algorithm (GA) is a framework or representation of biological evolution based on Charles Darwin's process of natural selection, created by John Holland and his coworkers in the 1960s and 1970s.

GA (Biological):

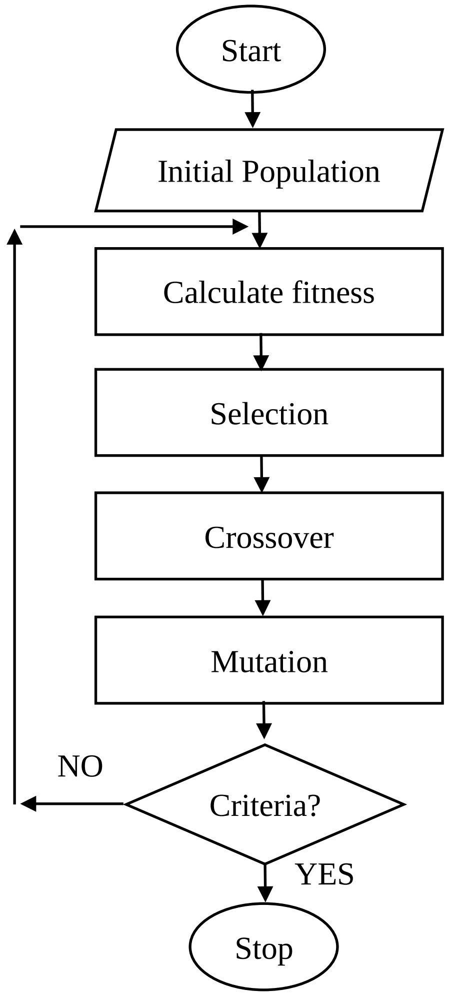
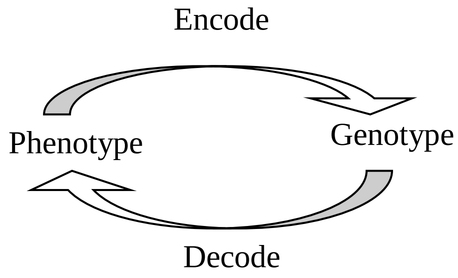


Figure 3.2: Flowchart of GA (biological)

- Abstraction of real biological evolution
- Solve a complex problem (like NP-hard)
- Focus on optimization
- Population of possible results for a given problem
- From a group of individuals, the best will survive



GA (DG):

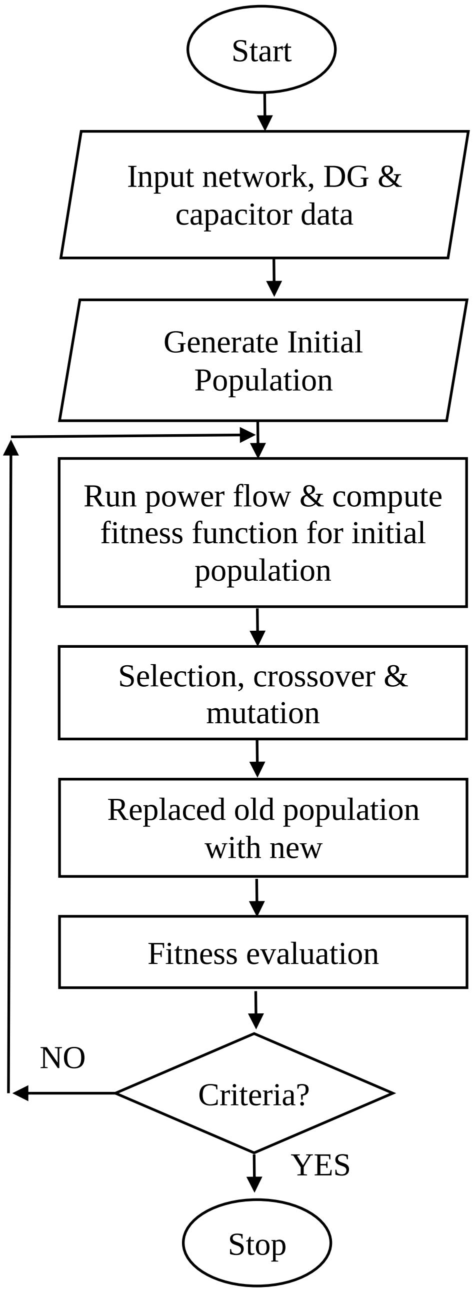


Figure 3.3: Flowchart of GA (for DG)

CHAPTER 4

DATA COLLECTION & ACQUISITION

4.1 Introduction

Some material and data are required for DG Implementation Analysis. For example, in DG Implementation, you have to select a distribution network, then you have to collect line data, load data, resistance, reactance, etc. of the network. The tabular form of all the data containing the DG Implementation Analysis of this chapter is given.

4.2 Line Data

Table 4.1: Line data (33 bus)

Sending Bus	Receiving Bus	R(ohm)	X(ohm)	Z(ohm)
1	2	0.0922	0.047	0.103488357
2	3	0.493	0.2511	0.553263238
3	4	0.366	0.1864	0.410732224
4	5	0.3811	0.1941	0.427682148
5	6	0.819	0.707	1.081947318
6	7	0.01872	0.6188	0.619083095
7	8	0.7114	0.2351	0.749240929
8	9	1.03	0.74	1.268266534
9	10	1.044	0.74	1.279662455
10	11	0.1966	0.065	0.207066559
11	12	0.3744	0.1238	0.394337165
12	13	1.468	1.155	1.867899623
13	14	0.5416	0.7129	0.895297141
14	15	0.591	0.526	0.791174443
15	16	0.7463	0.545	0.924115085
16	17	1.289	1.721	2.150200456
17	18	0.732	0.574	0.930215029
2	19	0.164	0.1565	0.226689766

19	20	1.5042	1.3554	2.02477821
20	21	0.4095	0.4874	0.636591714
21	22	0.7089	0.9373	1.175189559
3	23	0.4512	0.3083	0.546470795
23	24	0.898	0.7091	1.144214495
24	25	0.896	0.7011	1.137698207
6	26	0.203	0.1034	0.227816944
26	27	0.2042	0.1447	0.250271313
27	28	1.059	0.9337	1.411834512
28	29	0.8042	0.7006	1.066573017
29	30	0.5075	0.2585	0.56954236
30	31	0.9744	0.963	1.369972394
31	32	0.3105	0.3619	0.47684574
32	33	0.341	0.5302	0.63039118
20 (33*)	7	2	2	2.828427125
8 (34*)	14	2	2	2.828427125
11(35*)	21	2	2	2.828427125
17(36*)	32	2	2	2.828427125
24(37*)	28	2	2	2.828427125
Total		30.32992	27.7933	41.69068763

Table 4.2: Line data (14 bus)

Sending End Bus	Receiving End Bus	R (ohm)	X (ohm)	Z (ohm)
1	2	0.01934	0.05917	0.062250498
2	3	0.04699	0.19797	0.203470344
2	4	0.05822	0.17632	0.185683362
1	5	0.05403	0.22304	0.22949092
2	5	0.05695	0.17388	0.182968732
3	4	0.06701	0.17103	0.18368887
4	5	0.01335	0.04211	0.044175498
5	6	0	0.25202	0.25202
4	7	0	0.20912	0.20912
7	8	0	0.17615	0.17615
4	9	0	0.55618	0.55618
7	9	0	0.11001	0.11001
9	10	0.03181	0.0845	0.090289125
6	11	0.09498	0.1989	0.220414179
6	12	0.12291	0.25581	0.28380561
6	13	0.06615	0.13027	0.14610303
9	14	0.12711	0.27038	0.298767964
10	11	0.08205	0.19207	0.208861407
12	13	0.22092	0.19988	0.29792224
13	14	0.17093	0.34802	0.387730558
Total		1.23275	4.02683	4.329102337

Table 4.3: Line data (69 bus)

Sending Bus	Receiving Bus	R(ohm)	X(ohm)	Z(ohm)
1	2	0.0005	0.0012	0.0013
2	3	0.0005	0.0012	0.0013
3	4	0.0015	0.0036	0.0039
4	5	0.0251	0.0294	0.0387
5	6	0.366	0.1864	0.4107
6	7	0.3811	0.1941	0.4277
7	8	0.0922	0.047	0.1035
8	9	0.0493	0.0251	0.0553
9	10	0.819	0.2707	0.8626
10	11	0.1872	0.0619	0.1972
11	12	0.7114	0.2351	0.7492
12	13	1.03	0.34	1.0847
13	14	1.044	0.345	1.0995
14	15	1.058	0.3496	1.1143
15	16	0.1966	0.065	0.2071
16	17	0.3744	0.1238	0.3943
17	18	0.0047	0.0016	0.0050
18	19	0.3276	0.083	0.3380
19	20	0.2106	0.0696	0.2218
20	21	0.3416	0.1129	0.3598
21	22	0.014	0.0046	0.0147
22	23	0.1591	0.0526	0.1676
23	24	0.3463	0.1145	0.3647
24	25	0.7488	0.2475	0.7886
25	26	0.3089	0.1021	0.3253
26	27	0.1732	0.0572	0.1824
3	28	0.0044	0.0108	0.0117
28	29	0.064	0.1565	0.1691
29	30	0.3978	0.1315	0.4190
30	31	0.0702	0.0232	0.0739
31	32	0.351	0.116	0.3697
32	33	0.839	0.2816	0.8850
33	34	1.708	0.5646	1.7989
34	35	1.474	0.4873	1.5525
4	36	0.0034	0.0084	0.0091
36	37	0.0851	0.2083	0.2250
37	38	0.2898	0.7091	0.7660
38	39	0.0822	0.2011	0.2173
8	40	0.0928	0.0473	0.1042
40	41	0.3319	0.1114	0.3501
9	42	0.174	0.0886	0.1953
42	43	0.203	0.1034	0.2278
43	44	0.2842	0.1447	0.3189
44	45	0.2813	0.1433	0.3157
45	46	1.59	0.5337	1.6772

46	47	0.7837	0.263	0.8267
47	48	0.3042	0.1006	0.3204
48	49	0.3861	0.1172	0.4035
49	50	0.5075	0.2585	0.5695
50	51	0.0974	0.0496	0.1093
51	52	0.145	0.0738	0.1627

4.3 Load Data

Table 4.4: Load data (33 bus)

Bus Number	Bus Code	Load Bus		Apparent Power(S)
		KW(p)	KVAR(Q)	KVA
1	1	-	-	-
2	0	100	60	116.6190379
3	0	90	40	98.48857802
4	0	120	80	144.222051
5	0	60	30	67.08203932
6	0	60	20	63.2455532
7	0	200	100	223.6067977
8	0	200	100	223.6067977
9	0	60	20	63.2455532
10	0	60	20	63.2455532
11	0	45	30	54.08326913
12	0	60	35	69.46221995
13	0	60	35	69.46221995
14	0	120	80	144.222051
15	0	60	10	60.8276253
16	0	60	20	63.2455532
17	0	60	20	63.2455532
18	0	90	40	98.48857802
19	0	90	40	98.48857802
20	0	90	40	98.48857802
21	0	90	40	98.48857802
22	0	90	40	98.48857802
23	0	90	50	102.9563014
24	0	420	200	465.188134
25	0	420	200	465.188134
26	0	60	25	65
27	0	60	25	65
28	0	60	20	63.2455532
29	0	120	70	138.9244399
30	0	200	600	632.455532
31	0	150	70	165.5294536
32	0	210	100	232.594067
33	0	60	40	72.11102551
Total	0	3715	2300	4548.545984

Table 4.5: Load data (14 bus)

Bus Number	Load		Apparent Power (S)
	MW (P)	MVAR (Q)	MVA
1	0	0	0
2	21.7	12.7	25.14318993
3	94.2	19.1	96.11685596
4	47.8	-3.9	47.95883652
5	7.6	1.6	7.766595136
6	11.2	7.5	13.4792433
7	0	0	0
8	0	0	0
9	29.5	16.6	33.84981536
10	9	5.8	10.70700705
11	3.5	1.8	3.935733731
12	6.1	1.6	6.30634601
13	13.8	5.8	14.96930192
14	14.9	5	15.71655178
Total	259.3	73.6	275.9494767

Table 4.6: Load data (69 bus)

Bus number	Load Bus		Apparent power (s)
	KW (P)	KVAR (Q)	KVA
6	2.26	2.2	3.153981611
7	40.4	30	50.32057233
8	75	54	92.4175308
9	30	22	37.20215048
10	28	19	33.83784863
11	145	104	178.4404663
12	145	104	178.4404663
13	8	5	9.433981132
14	8	5.5	9.708243919
16	45.5	30	54.5
17	60	35	69.46221995
18	60	35	69.46221995
20	1	0.6	1.166190379
21	114	81	139.8463442
22	5	3.5	6.103277808
24	28	20	34.40930107
26	14	10	17.20465053
27	14	10	17.20465053
28	26	18.6	31.96810911
29	26	18.6	31.96810911
33	14	10	17.20465053
34	19.5	14	24.00520777
35	6	4	7.211102551
36	26	18.55	31.9390435

37	26	18.55	31.9390435
39	24	17	29.41088234
40	24	17	29.41088234
41	1.2	1	1.562049935
43	6	4.3	7.381734214
45	39.22	26.3	47.22180005
46	39.22	26.3	47.22180005
48	79	56.4	97.06678114
49	384.7	274.5	472.5932077
50	384.7	274.5	472.5932077
51	40.5	28.3	49.40789411
52	3.6	2.7	4.5
53	4.35	3.5	5.58323383
54	26.4	19	32.52629705
55	24	17.2	29.52693685
59	100	72	123.2233744
61	1244	888	1528.424025
62	32	23	39.40812099
64	227	162	278.8781096
65	59	42	72.42237223
66	18	13	22.20360331
67	18	13	22.20360331
68	28	20	34.40930107
69	28	20	34.40930107
Total	3801.55	2694.1	4660.13788

CHAPTER 5

RESULT & DISCUSSION

5.1 Introduction

Real power loss, reactive power loss, voltage, and angle are calculated through MATLAB in a conventional case (beyond DG). Analysis of DG size and allocation for IEEE-33/14/69 bus systems with GA, as well as a comparison of beyond DG and including DG. The statistics and graphs indicate how much power loss is reduced and how the voltage profile is upgraded.

MATrix LABoratory (MATLAB) is a simulation-based program that works with large amounts of data. In an IEEE-33 bus system with iteration 2000 and population 50, finding the DG Optimal solution takes a total of 2097.2106 seconds execution time Where are using a PC of the configuration Intel Core i5-8250u, up to 3.4 GHz, 8 GB RAM.

5.2 Conventional Case

Active Power-Loss= 206.7320 kW

Reactive Power-Loss= 137.9097 kVAr

Total Ploss = 248.5099 KVA = 0.2485 MVA

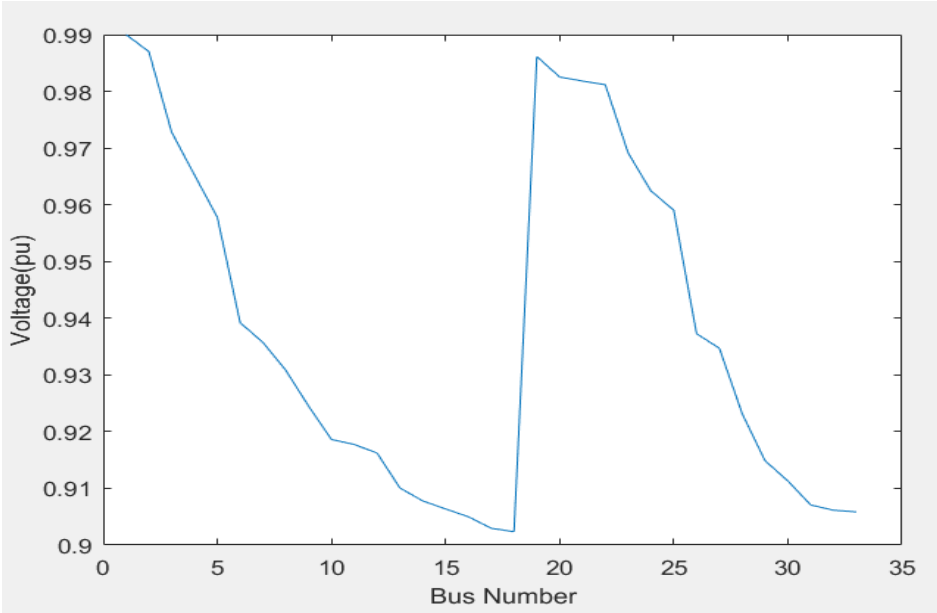


Figure 5.1: Voltage Profile (Beyond DG)

5.3 Power Losses

Table 5.1: Result sheet of P_{losses}, Q_{losses}, Angles, Voltages

Sr	Ploss (kw)	Qloss (kw)	Angle	Voltage
1	12.4706004	6.35703059	0	0.99
2	52.7580203	26.8712756	0.000264801	0.98700509
3	20.2607189	10.3185738	0.001758392	0.97278406
4	19.0342101	9.69441138	0.002960778	0.96524021
5	38.9296987	33.6059792	0.004181214	0.95778216
6	1.95843516	6.47371621	0.002586841	0.93921113
7	4.949745	1.63576757	-0.00155448	0.935717
8	4.27821541	3.07366933	-0.00095924	0.93081182
9	3.64368844	2.58269104	-0.00234284	0.92448429
10	0.56649316	0.18729428	-0.00353755	0.91861518
11	0.90162316	0.29813287	-0.00342019	0.91774385
12	2.72870607	2.1469043	-0.00323712	0.91622455
13	0.74634705	0.98240548	-0.00496593	0.9100624
14	0.36559787	0.32538829	-0.00641001	0.90778888
15	0.2882205	0.21047859	-0.00710946	0.90636992
16	0.25766015	0.34401328	-0.00755131	0.90499237
17	0.05440801	0.0426642	-0.00897304	0.90296399
18	0.26460486	0.25708767	-0.00915685	0.90235263
19	0.84990342	0.76582841	-5.85E-05	0.98614165
20	0.10290575	0.12022005	-0.00126415	0.98252994
21	0.04456512	0.05892353	-0.0016118	0.98181919

22	3.24980719	2.22055753	-0.00197709	0.98117642
23	5.25431406	4.14903575	0.001202352	0.96916072
24	1.31523943	1.02914549	-0.0003902	0.96242055
25	2.65626648	1.35299485	-0.00117755	0.95906163
26	3.40097091	1.73159919	0.003323055	0.93727204
27	11.5486527	10.1822257	0.004369386	0.93469623
28	8.00684526	6.97537403	0.006057039	0.92315647
29	3.98217459	2.02835888	0.007602323	0.91487098
30	1.63162154	1.61253237	0.009550515	0.91130499
31	0.21827902	0.25441281	0.00811503	0.90707357
32	0.01348264	0.02096334	0.007719031	0.90614167
33	206.732021	137.909656	0.007585724	0.9058528

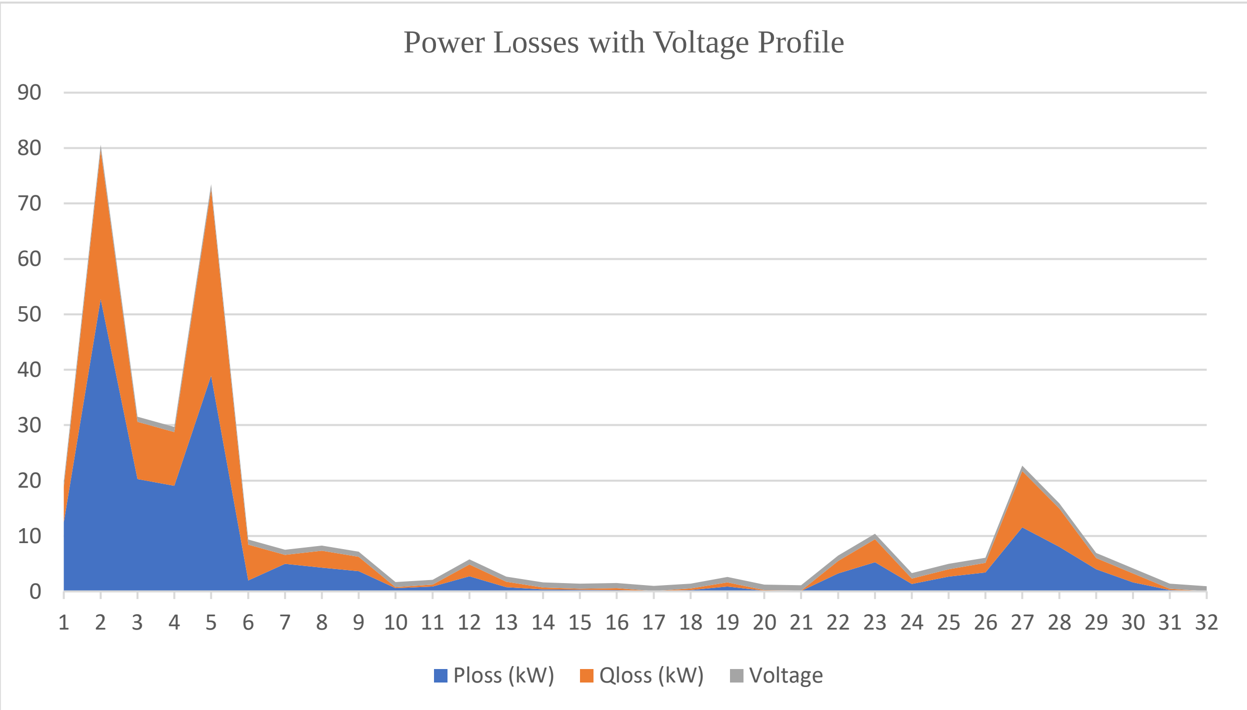


Figure 5.2: Graph of P_{loss}, Q_{loss} & *Voltages*

5.4 DG Size & Allocation

IEEE-33 bus:

Table 5.2: DG Size & Allocation (33 bus)

Terms	Beyond DG					Including DG				
Tie Switch Number	33	34	35	36	37	33	34	35	36	37
Active Power Loss (kW)			202.6771					153.9078		
Reactive Power Loss (kVAR)			135.141					97.6984		
DG Location						8	33	3	16	
DG Size (kVA)						24	670	631	457	
Minimum Voltage (pu)			0.91306					0.95		
Maximum Voltage (pu)			1					1		
Execution Time (Second)			1.2117					2097.2106		

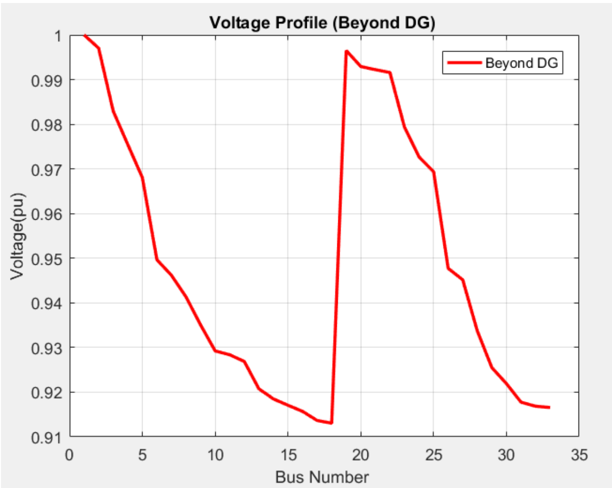


Figure 5.3: Voltage profile of 33 bus (beyond DG)

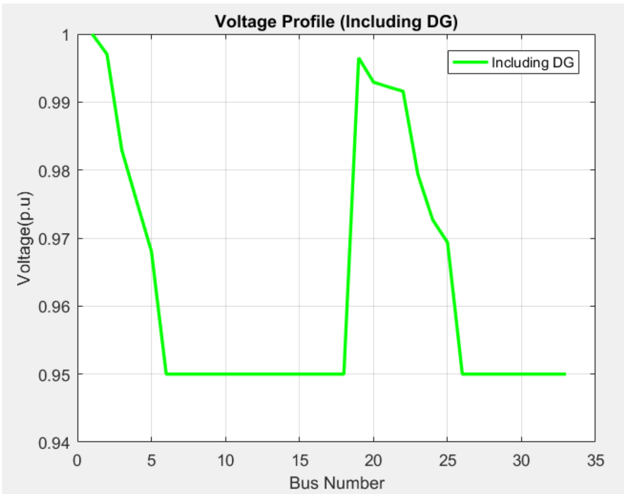


Figure 5.4: Voltage profile of 33 bus (including DG)

IEEE-14 bus:

Table 5.3: DG Size & Allocation (14 bus)

Terms	Without DG	With DG								
Power Losses (KW)	10.599	4.0645								
Stability Index	2.0477	0.9577								
DG Location	-	3	8	4	13					
DG Size (KVA)	-	0.6217	0.0152	0.0112	0.0304					
Eigen Value	-	64.8136	40.0068	21.9727	18.8255	16.2848	11.2718	2.7945	5.55	7.6642

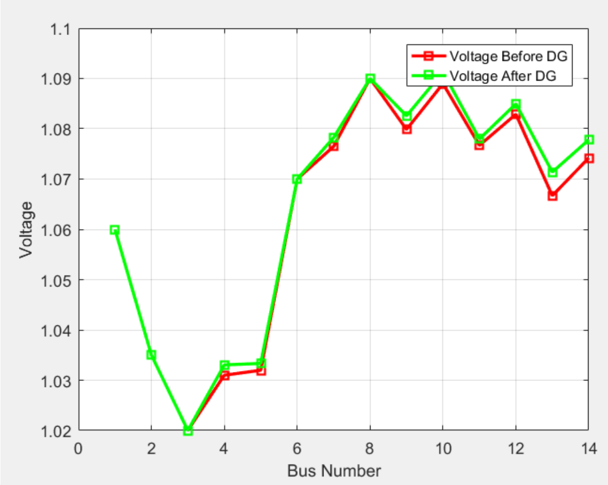


Figure 5.5: Voltage profile-14 Bus (before DG vs after DG)

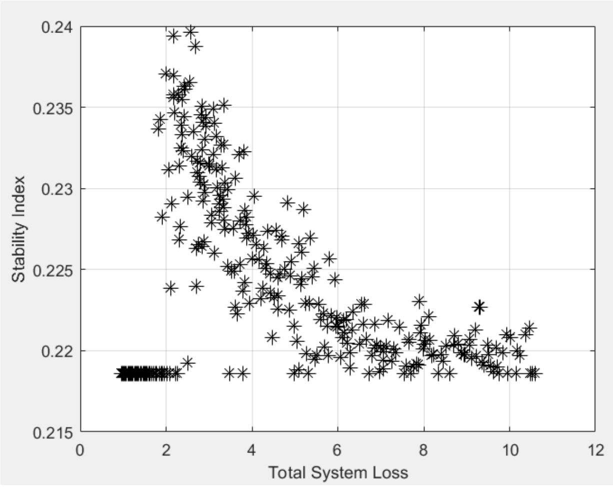


Figure 5.6: Stability index vs Total System Loss Graph (14 bus)

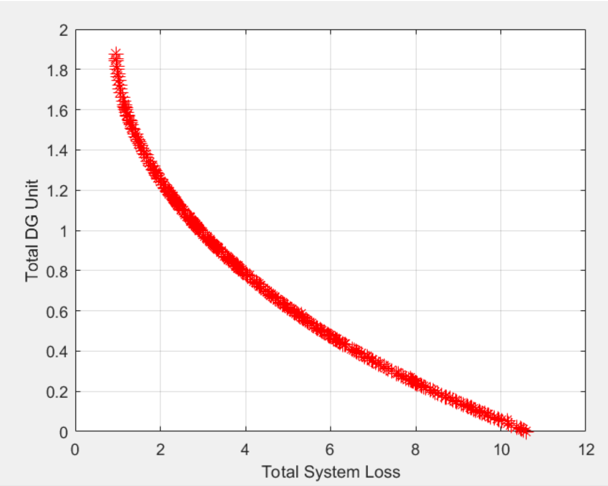


Figure 5.7: Total DG Unit vs Total System Loss graph (14 bus)

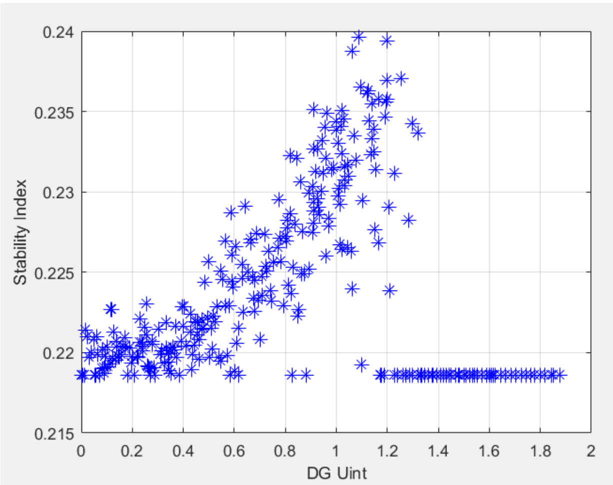


Figure 5.8: Stability Index vs DG Unit graph (14 bus)

IEEE-69 bus:

Table 5.3: DG Size & Allocation (69 bus)

Terms	Beyond DG					Including DG				
Tie Switch Number	69	70	71	72	73	69	70	71	72	73
Active Power Loss (kW)	224.9606					137.4267				
Reactive Power Loss (kVAR)	102.147					70.5641				
DG Location	-					50	69	5	30	
DG Size (kVA)	-					644	702	182	943	
Minimum Voltage (pu)	0.90901					0.95				
Maximum Voltage (pu)	1					1				
Execution Time (Second)	1.2518					2839.788				

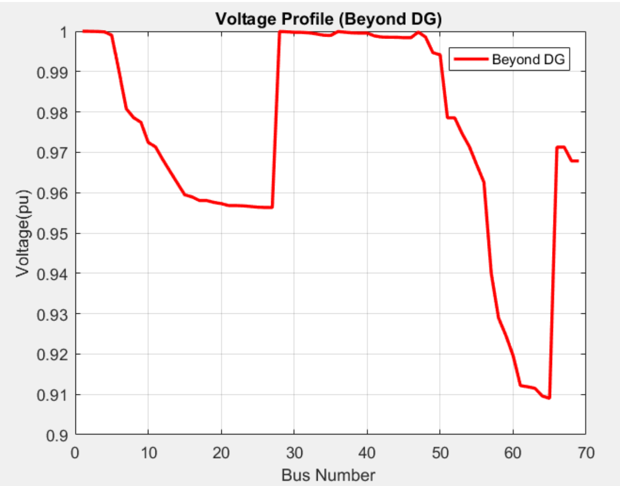


Figure 5.9: Voltage profile of 69 bus (beyond DG)

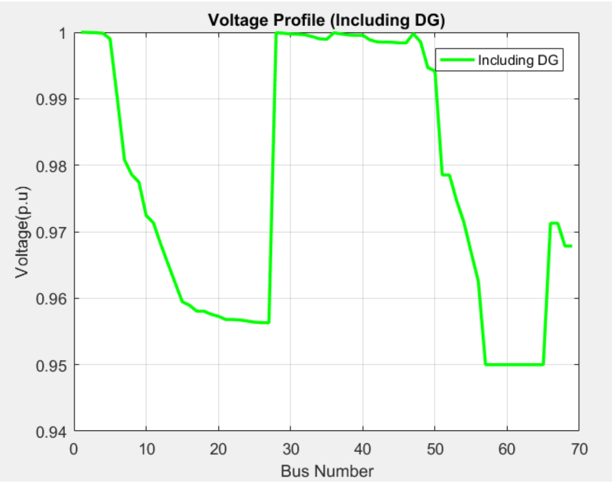


Figure 5.10: Voltage profile of 69 bus (including DG)

5.5 Overall Comparison

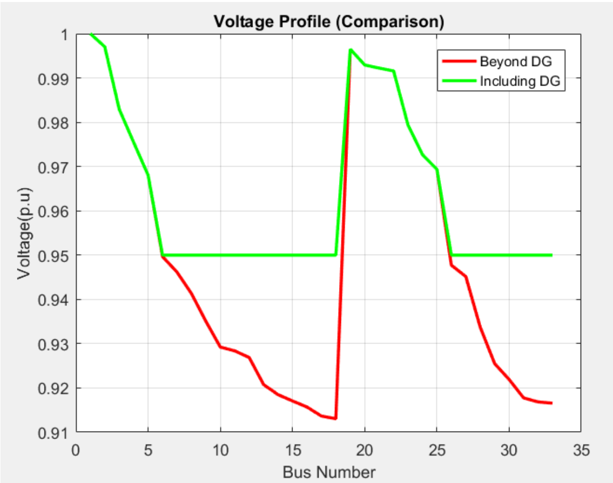


Figure 5.11: Voltage profile comparison of 33 bus (beyond vs including DG)

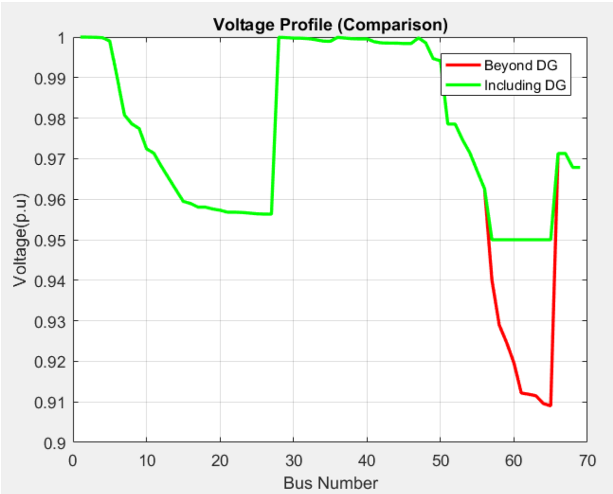


Figure 5.12: Voltage profile comparison of 69 bus (beyond vs including DG)

5.6 Chapter Summery

Real power, reactive power and voltage have been extracted through backward/forward analysis & the power loss in the conventional case (without DG) is shown through the graph. Then IEEE 33/14/69 bus systems adding DG to using genetic algorithms to show the size of DG, allocation and reduction of power loss, voltage profile upgrade is shown. The two cases discussed here are beyond DG and Including Dg. Beyond DG & Including DG Comparison for all bus systems has been drawn in tabular form. Five tie switch has been used to get non-interruptible and excellent voltage at the consumer end. Voltage profile comparison has been shown in different bus systems after final DG implementation. Power Loss Reduction of IEEE-33/14/69 bus system half of it.

CHAPTER 6

COST ANALYSIS OF RENEWABLE ENERGY IN DG

6.1 Introduction

Renewable energy refers to energy from a source that is not wasted during use. That unlimited amount of energy we can use. Such as wind or sun.

Renewable energy is now becoming a much more essential energy source as we develop novel and different methods to gather and harness renewables such as the wind and sun. From photovoltaic panels to massive offshore wind turbines and storage factories, renewable energy is expanding on a big and small scale. Some rural villages depend exclusively on renewable properties for lighting and heat.

Renewable energy sources are responsible for the growing share of energy consumption in Europe, the United States and the world at large. Low cost, suitable for the environment, less polluted, safe, endless. Source. Although costs can sometimes be a barrier to adopting renewable sources. In recent decades, tremendous improvements in technology, supply networks, and government regulation have all contributed to their expansion. They offer a stable power source as well as fuel diversity. They contribute to energy conservation, environmental improvement, and the preservation of natural resources and ecosystems. They also lessen the demand for costly fuel imports.

Renewable energy technology uses resources directly from the environment to generate electricity. The great advantage of these resources is that they will not simply run out, which is not the case for many types of fossil fuels - when fossil fuels are regenerated, it takes millions of years for that to happen.

Renewable energy technology depends entirely on weather conditions. Without wind, the wind turbine cannot rotate. If it is not sunny, less solar energy can be captured. If atmospheric conditions are not favorable enough, renewable energy technologies cannot produce any electricity. For example, moving wind blades of wind turbines requires minimal wind speed while hydro generators require sufficient water flow to rotate turbines.

This is especially problematic when we consider the fact that when renewable technologies are at work, they produce excess energy that cannot be stored attributed to a shortage of extended storage solutions. Installing renewable energy generation facilities, even on a small scale at home, requires a potentially huge capital investment and plenty of space for installation. While this is true for solar panels on residential house rooftops, it becomes much more difficult when 40 hectares of green land are required to contain photovoltaic power that only provides 20 MW of power. In the meanwhile, a nuclear power plant could potentially create 180 megawatts of electricity in the same amount of area.

Although renewable sources are clearly a better alternative than fossil fuels, it still creates pollution. Several more renewable energy technologies are manufactured via polluting industrial processes, and many of the resources required for renewable energy are derived from fossil fuels. There are however certain forms of renewable energy that generate pollution directly, the most notable of which is biomass energy, which necessitates the combustion of plant material, emancipating contaminants into the atmosphere.

We are rapidly moving towards a future of renewable and clean energy. This is a top priority for most developed countries, although renewable energy faces a number of challenges, such as long-term storage, high access costs and complex reliability. [15]

6.1.1 Wind Turbine & Photovoltaic Cell

Wind Turbine:

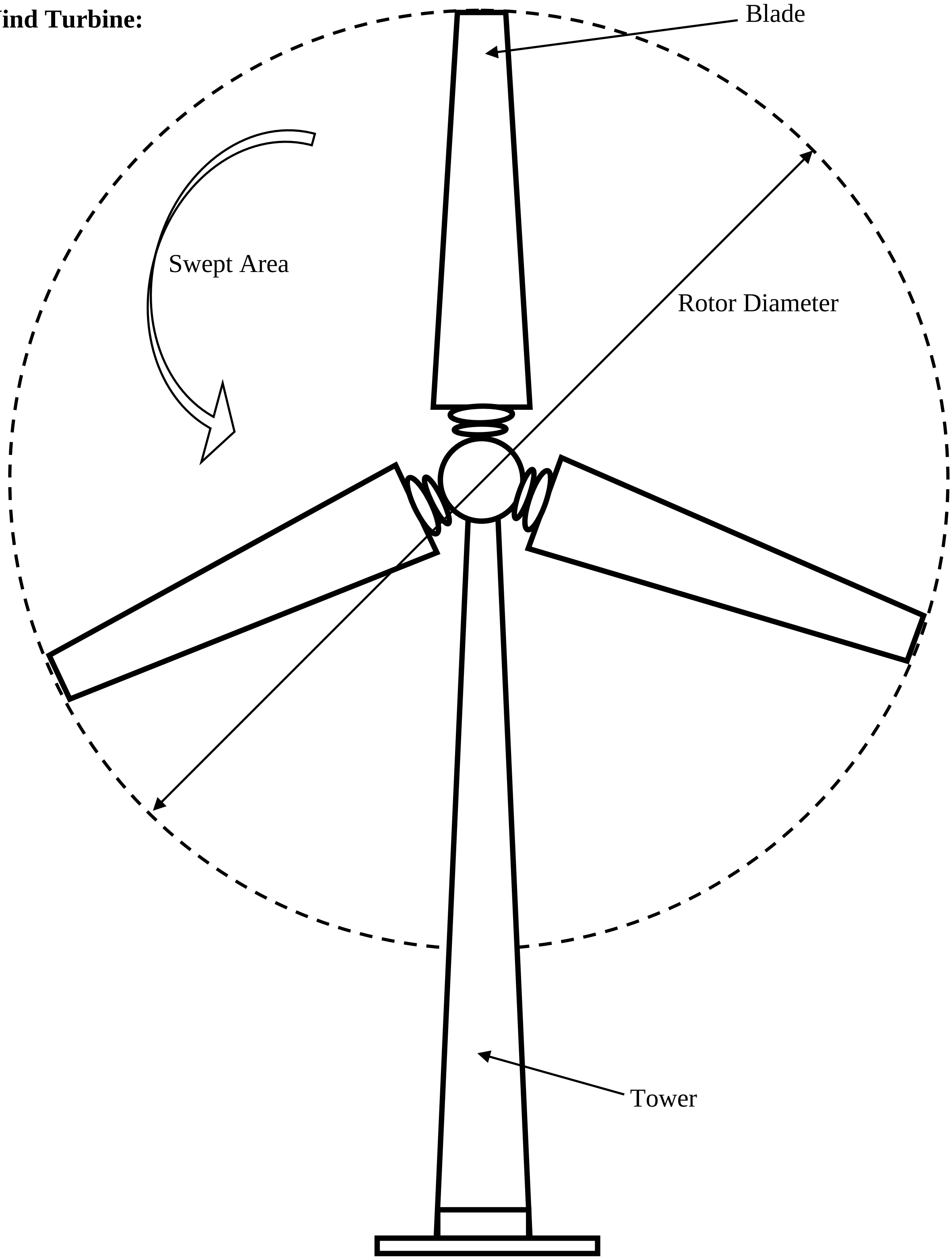


Figure 6.1: Wind Turbine

Wind Turbine works by transforming the kinetic energy of wind to electrical energy. The energy existing for renovation generally depends on the wind speed and the swept area of the turbine. [10]

Photovoltaic Cell:

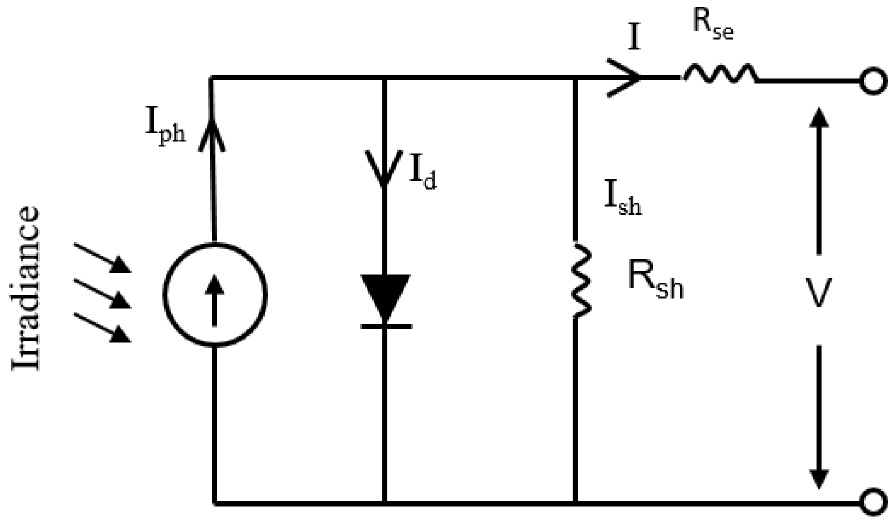


Figure 6.2: PV Cell Equivalent Circuit

The most common kind is single-crystal silicon. The transistor sector and the solar cell industry, which have produced arrays for producing electricity in space for more than two decades, have developed knowledge of silicon's electrical characteristics and skill with its fabrication. In nature, single-crystal silicon does not occur. Rather, it exists as silica, or silicon dioxide ($Si0_2$), a compound of the two most abundant elements on the planet's surface. (Nearly 60% of the rock is made up of Silica) Quartzite, which can be nearly 99% silica in high-grade mineral deposits, is the most common starting point for producing silicon for solar cells. Other minerals with a high silicon content, such as sand, are not suitable as raw materials because they contain too many impurities, which are expensive to remove. Silicon is an excellent solar cell material because of its relative availability and low cost.

The Sun Power Maxeon M-Series, which has a maximum efficiency of 22.8 percent and a maximum power output of 420-435 watts, was used in the analysis for solar plant deployment.

6.2 Modelling of Wind & Solar DGs

$$P_{wind}(t) = 0.5\alpha\rho(t)Av(t)^3 \quad (6.1)$$

Where,

α = Albert Betz constant

$\rho(t)$ = Air density

A = Swept area

$v(t)$ = wind speed

$$P_{pv}(t) = A\beta\mu(t) \quad (6.2)$$

Where,

A = Panel area

$\mu(t)$ = Solar irradiance

β = Panel Efficiency

Solar Power Produce:

$$Solar\ Power = \sqrt{(Area * Efficiency * \ irradiance)^2 + \ (Area * Efficiency * irradiance * \sin(\cos^{-1}(pf)))^2} \quad (6.3)$$

Wind Power Produce:

$$Wind\ Power_{real} = 0.5 * betz\ constant * air\ density * swept\ area * (wind\ speed)^3 \quad (6.4)$$

$$Wind\ Power_{reactive} = \ Wind\ Power_{real} * \ \sin(\cos^{-1}(pf)) \quad (6.5)$$

$$Wind\ Power_{Total} = \ \sqrt{Wind\ Power_{real}{}^2 + \ Wind\ Power_{reactive}{}^2} \quad (6.6)$$

6.3 PV Module Design

PV module design for irradiance of 189.79 W/m^2 and temperatures of 25°C. "SunPower SPR-X21-345-COM" is the model name of the chosen PV panel. When the irradiance is 189.79W/m^2, the temperature is 25°C, and there are 22 parralel strings and 10 series-connected modules per string, the panel efficiency is 21% and the maximum power is 344.95W. The I-V and P-V curves are shown below.

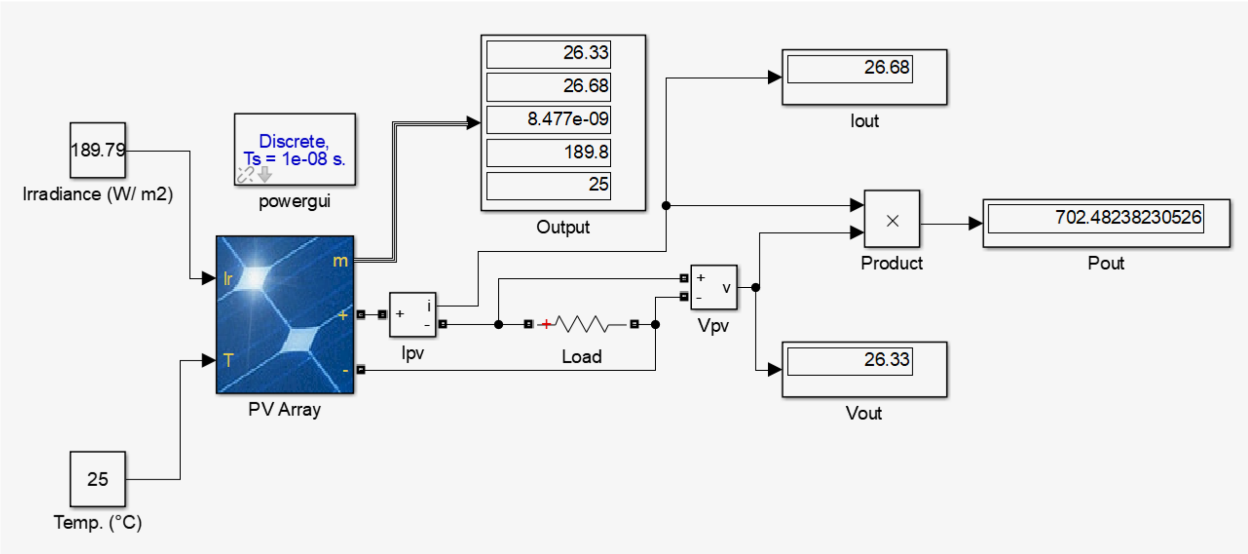


Figure 6.3: PV Module Simulation Design in Simulink

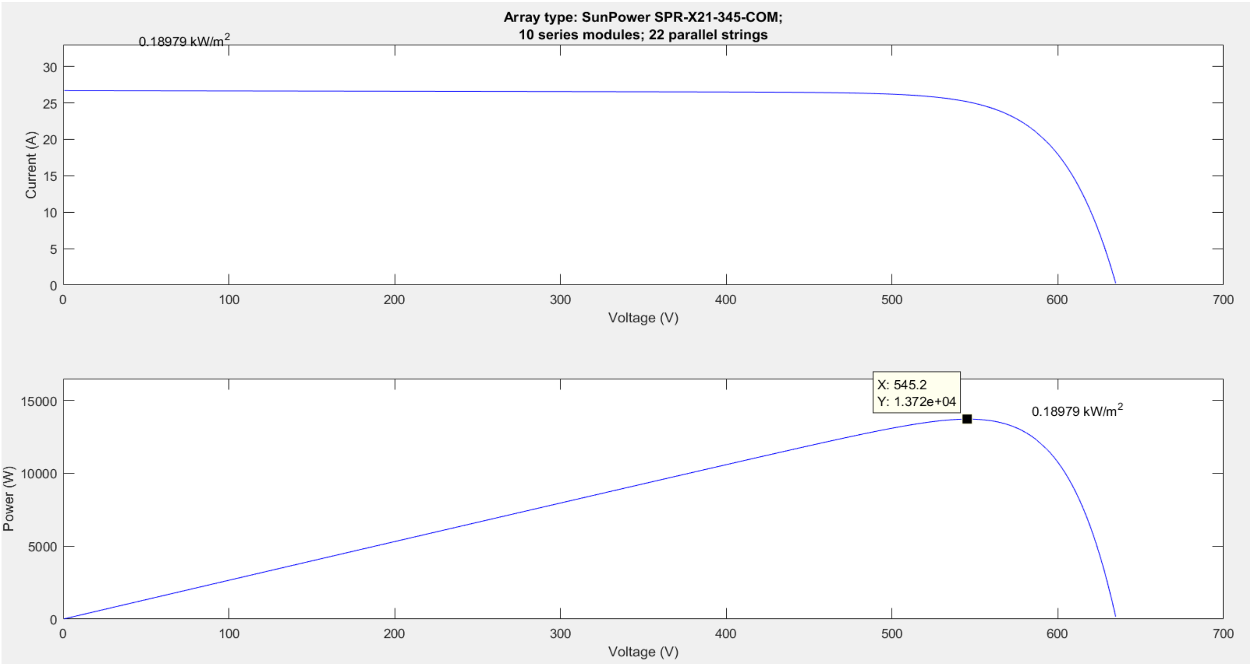


Figure 6.4: I-V & P-V Curve of PV Module

Table 6.1: PV Module Data Sheet

Terms	Value
Max Power (W)	344.946
V_{oc}	68.2
V_{mp}	57.3
N_{cell}	96
Series module/string	10
Parallel String	22
I_{sc}	6.39
I_{mp}	6.02
I_0	1.91E-10
I_L	6.3928
R_{sh} (Ω)	884.5543
R_s (Ω)	0.39387
Diode Ideality Factor	1.1415
Temp. Coefficient of V_{oc} (%/°C)	-0.356
Temp. Coefficient of I_{sc} (%/°C)	0.07

6.4 Wind & Solar Data Collection

Wind data collected by NASA & solar data collected by ANN forecast analysis.

6.4.1 Wind Data

Table 6.2: Wind Data Sheet (Barishal)

Sr.	Latitude (degree)	Longitude (degree)	Elevation (m)	Month	Relative Humidity (%)	Wind Speed (m/s)
1	22.7	90.4	5	Jan	54	2.6
2	22.7	90.4	5	Feb	47.2	2.5
3	22.7	90.4	5	Mar	48.2	3
4	22.7	90.4	5	Apr	59.2	3.8
5	22.7	90.4	5	May	69.9	4
6	22.7	90.4	5	Jun	82.6	4.4
7	22.7	90.4	5	Jul	87.7	4.5
8	22.7	90.4	5	Aug	88.3	3.9
9	22.7	90.4	5	Sep	87.8	3.1
10	22.7	90.4	5	Oct	81.3	2.3
11	22.7	90.4	5	Nov	71.6	2.2
12	22.7	90.4	5	Dec	64.1	2.3

Table 6.3: Wind Data Sheet (Cox's Bazar)

Sr.	Latitude (degree)	Longitude (degree)	Elevation (m)	Month	Relative Humidity (%)	Wind Speed (m/s)
1	21.4	92	9	Jan	63.8	4.5
2	21.4	92	9	Feb	67.6	3.8
3	21.4	92	9	Mar	74.6	3.5
4	21.4	92	9	Apr	79	3.6
5	21.4	92	9	May	82.1	4.3
6	21.4	92	9	Jun	86.6	5.6
7	21.4	92	9	Jul	88.2	5.8
8	21.4	92	9	Aug	88.2	5.3
9	21.4	92	9	Sep	85.6	4.2
10	21.4	92	9	Oct	78.6	3.7
11	21.4	92	9	Nov	71	4.1
12	21.4	92	9	Dec	66.6	4.2

Table 6.4: Wind Data Sheet (Sundarban)

Sr.	Latitude (degree)	Longitude (degree)	Elevation (m)	Month	Relative Humidity (%)	Wind Speed (m/s)
1	22.8	89.6	5	Jan	49.7	2.5
2	22.8	89.6	5	Feb	42.9	2.5
3	22.8	89.6	5	Mar	43.7	2.9
4	22.8	89.6	5	Apr	55	3.7
5	22.8	89.6	5	May	66.5	3.8
6	22.8	89.6	5	Jun	81.1	4.1
7	22.8	89.6	5	Jul	87.3	4.1
8	22.8	89.6	5	Aug	88	3.5
9	22.8	89.6	5	Sep	87.9	2.8
10	22.8	89.6	5	Oct	81.1	2.2
11	22.8	89.6	5	Nov	70	2.1
12	22.8	89.6	5	Dec	60.8	2.3

6.4.2 Solar Data

Table 6.5: Solar Data Sheet (Khulna)

Sr.	Latitude (degree)	Longitude (degree)	Elevation (m)	Month	Daylight hour (Hr)	Min. Temp. (°C)	Max. Temp. (°C)	Relative Humidity (%)	Irradiance (kWh/m^2/day)
1	22.334	89.776	11	Jan	10.9	14.2	34	52.7	4.29
2	22.334	89.776	11	Feb	11.4	17.9	39.1	50.8	4.88
3	22.334	89.776	11	Mar	12	21.8	42.2	54.6	5.58
4	22.334	89.776	11	Apr	12.6	23.6	38.6	70.3	5.83
5	22.334	89.776	11	May	13.2	24.9	36.2	78.7	5.53
6	22.334	89.776	11	Jun	13.4	25.6	33.5	84.8	4.2
7	22.334	89.776	11	Jul	13.3	25.3	32	86.7	3.89
8	22.334	89.776	11	Aug	12.9	25.3	32.2	86.4	3.9
9	22.334	89.776	11	Sep	12.2	24.6	32.6	84.8	3.83
10	22.334	89.776	11	Oct	11.6	22.4	32.6	80.6	4.29
11	22.334	89.776	11	Nov	11.1	18.1	32	71	4.23
12	22.334	89.776	11	Dec	10.8	15	33.1	57.6	4.21

Table 6.6: Solar Data Sheet (Bandarban)

Sr.	Latitude (degree)	Longitude (degree)	Elevation (m)	Month	Daylight hour (Hr)	Min. Temp. (°C)	Max. Temp. (°C)	Relative Humidity (%)	Irradiance (kWh/m^2/day)
1	21.744	92.381	240	Jan	10.9	10.7	30.9	52.7	4.8
2	21.744	92.381	240	Feb	11.4	13.7	34	53	5.32
3	21.744	92.381	240	Mar	12	18	37.5	58.4	5.84
4	21.744	92.381	240	Apr	12.6	21.3	37.3	68.2	5.92
5	21.744	92.381	240	May	13.1	23.1	35	77.1	5.31
6	21.744	92.381	240	Jun	13.4	23.9	30.9	85.6	3.86
7	21.744	92.381	240	Jul	13.3	23.5	29.9	87.1	3.81
8	21.744	92.381	240	Aug	12.8	23.3	30.5	86.3	3.95
9	21.744	92.381	240	Sep	12.2	22.6	31.2	84.4	4.25
10	21.744	92.381	240	Oct	11.6	20.8	31.7	78.4	4.4
11	21.744	92.381	240	Nov	11.1	16.8	30.6	69.7	4.34
12	21.744	92.381	240	Dec	10.8	12.4	30.3	59.3	4.48

Table 6.7: Solar Data Sheet (Rangpur)

Sr.	Latitude (degree)	Longitude (degree)	Elevation (m)	Month	Air Temp. (°C)	Relative Humidity (%)	Irradiance (kWh/m^2/day)
1	25.7	89.3	35	Jan	16.8	53.5	4.35
2	25.7	89.3	35	Feb	20.5	41.4	5.22
3	25.7	89.3	35	Mar	25.9	32.3	6.1
4	25.7	89.3	35	Apr	30.1	39.6	6.2
5	25.7	89.3	35	May	31.3	55.6	5.74
6	25.7	89.3	35	Jun	30.6	71.7	4.77
7	25.7	89.3	35	Jul	29.3	82.6	4.19
8	25.7	89.3	35	Aug	29	83.1	4.29
9	25.7	89.3	35	Sep	28	83.2	3.89
10	25.7	89.3	35	Oct	25.7	76.8	4.67
11	25.7	89.3	35	Nov	21.7	70.7	4.66
12	25.7	89.3	35	Dec	17.9	65.2	4.26

6.4.3 Solar Plant Area Selection (google earth)

Google Earth is a geospatial analytic tool that allows users to see and study satellite photos of our world in the cloud. Scientists and non-profits utilize Earth Engine for remote sensing research, disease outbreak prediction, natural resource management, and other purposes. Google Earth has a variety of tools, the most noteworthy of which are the Measure distance and Area Tools, which can be used to define the area by selecting a location. These tools have helped us to select the area of the rooftop solar panel.

Appendix I includes a snapshot of the chosen location and area measurement of the Rooftop solar plant.

6.5 Result & Discussion of Renewable Energy

Wind & Solar Plant Size, Plant Area, Swift Area of Wind Turbine, Solar Output, Usage of Renewable in DG has been released in different bus systems.

6.5.1 Wind & Solar Plant Size

Table 6.8: Plant Size of Wind & Solar

Bus System	Power Required (KVA)	Wind Speed (m/s)	Irradiance (W/m^2)	Plant Area (m^2)	Swept Area (m^2)
IEEE-33	24	3.22	-	-	1978.01
	670	3.22	-	-	55219.36
	631	-	195.42	13517.39	-
	457	-	195.42	9789.93	-
IEEE-14	0.622	-	189.79	13.72	-
	0.030	-	189.79	0.00066	-
	0.011	3.04	-	-	0.0011
	0.015	3.04	-	-	1.469
IEEE-69	644	-	202.57	13309	-
	943	-	202.57	19489.46	-
	182	4.38	-	-	5959.86
	702	4.38	-	-	22988.04

6.5.2 Usages of Solar & Wind Power in DGs

Photovoltaics, the most significant solar technology for solar energy distribution, converts sunlight into electricity using solar cells incorporated into solar panels. Crystal silicon is utilized in solar, or photovoltaic (PV) technology, when thin-film solar cell technology or other components are employed. The issues are considerably reduced by this technique.

Wind energy is unpredictable and non-transferable, much as solar energy. High winds pose a significant risk to wind turbines and generators. Wind hybrid power systems mix wind electricity with other DER technologies to provide distributed generation. They are in great demand since them essential tiny maintenance and emit little pollutants. Installation, maintenance, and production costs for solar and wind power are much cheaper than for bioenergy, geothermal, and hydropower. The usage of dispersed generations has lowered environmental pressures, greenhouse gas emissions, and pollution levels.

6.6 Cost Analysis

RETScreen Expert is a green power management software framework that helps professionals and decision-makers to identify and assess the viability of potential energy efficiency, renewable energy, and cogeneration projects; to measure and verify the actual and ongoing energy performance of buildings, factories, and power plants around the world; and to manage facility portfolios.

Here is a cost evaluation of a Small Renewal Power Plant using RETScreen Expert for DG Installation. First, a facility located in Bangladesh has been determined for the power plant's cost investigation. NASA's satellite survey yielded climate information. PV and wind turbines were selected as power plants, with a combined capacity of 1669 kW.

GHG emissions, financial feasibility, cash flow, net present value, energy production cost, and GHG reduction cost were all included in this cost analysis.

6.6.1 Feasibility of placement

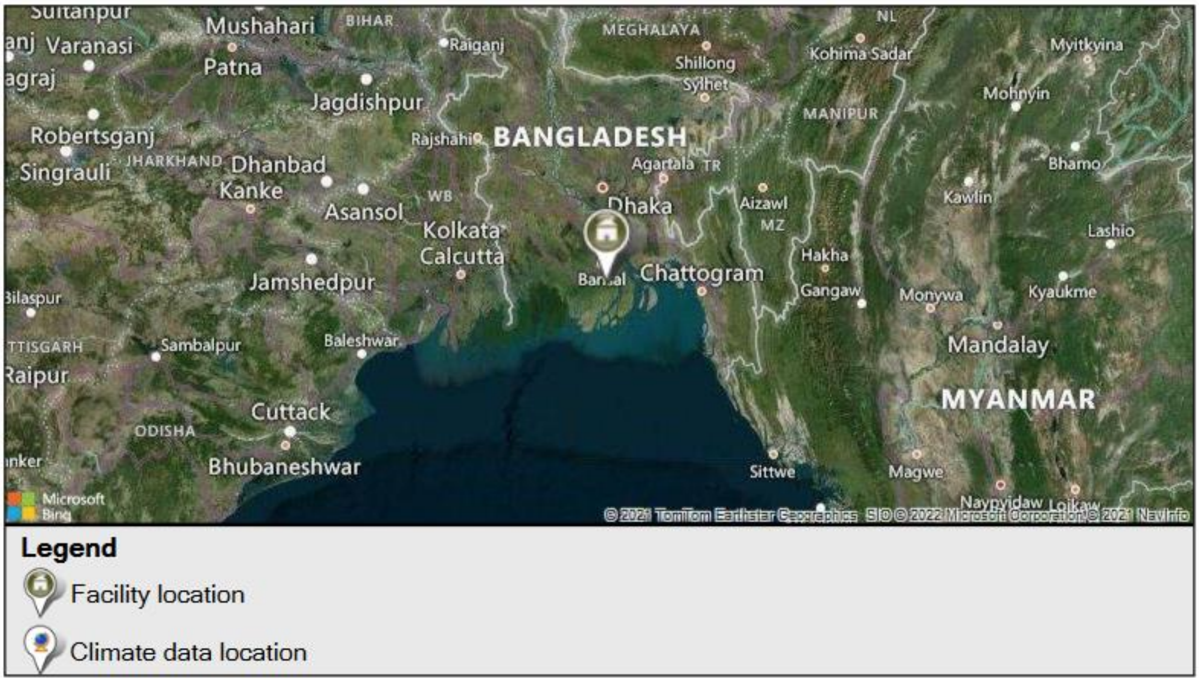


Figure 6.5: Power plant location selection

Table 6.9: Location selection

Terms	Unit	Climate data location	Facility location
Place		Banglaesh - Barishal	Bangladesh
Latitude	°N	22.7	22.7
Longitude	°E	90.4	90.4
Climate zone		1A -Very hot - Humid	1A -Very hot - Humid
Elevation	m	5	4

6.6.2 Climate Data

Table 6.10: Climate data set

Month	Air Temp.	Relative Humidity	Precipition	Daily solar irradiance	Atm. pressure	wind speed	Earth temp.	Heating degree-days 18 °C	Cooling degree-days 10 °C
	(°C)	(%)	(mm)	(kWh/m^2/day)	(kPa)	(m/s)	(°C)	(°C-d)	(°C-d)
Jan	18.9	54.00%	6.2	4.35	101.4	2.6	18.6	0	276
Feb	22.8	47.20%	14.28	4.95	101.2	2.5	22.9	0	358
Mar	27.7	48.20%	30.69	5.57	100.9	3	28.5	0	549
Apr	30.1	59.20%	65	5.65	100.6	3.8	31.4	0	603
May	30.1	69.90%	161.82	5.25	100.3	4	31	0	623
Jun	29.1	82.60%	258.6	4.05	100	4.4	29.4	0	573
Jul	28.3	87.70%	310.31	3.89	100	4.5	28.4	0	567
Aug	28	88.30%	254.2	3.91	100.1	3.9	28.2	0	558
Sep	27.6	87.80%	209.4	3.83	100.5	3.1	27.7	0	528
Oct	26.3	81.30%	124	4.29	100.9	2.3	26.4	0	505
Nov	23.1	71.60%	26.4	4.23	101.2	2.2	22.8	0	393
Dec	19.5	64.10%	8.06	4.24	101.4	2.3	19.1	0	295
Annual	26	73.30%	1469.66	4.51	100.7	3.2	26.2	0	5,828

6.6.3 Benchmark

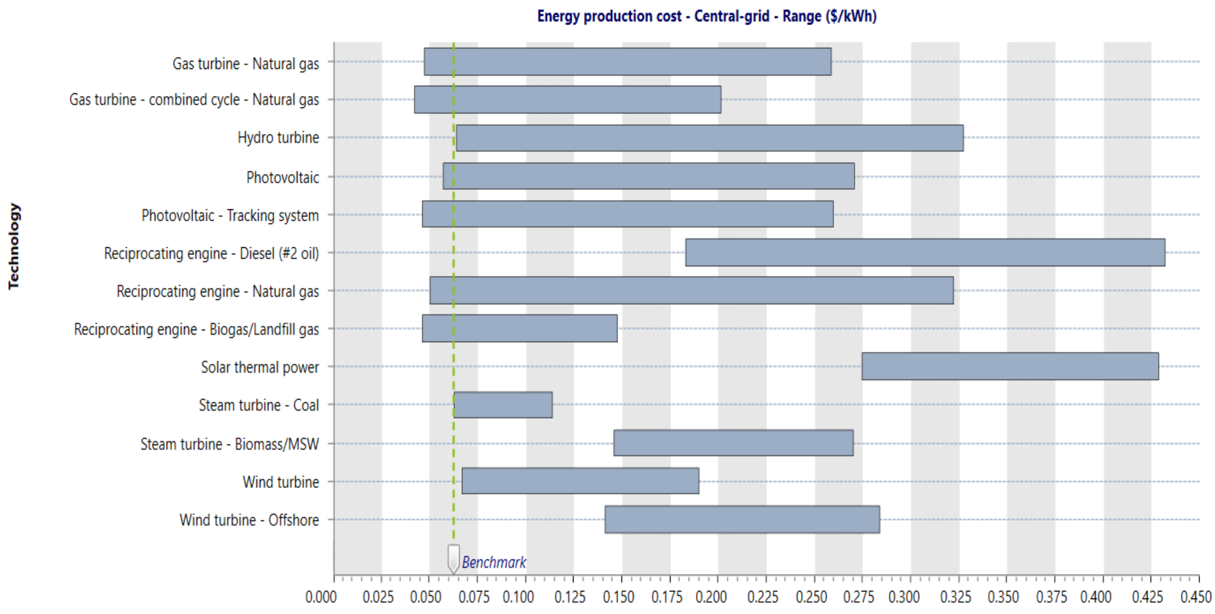


Figure 6.6: Benchmark of Energy production cost

6.6.4 Power Plant Capacity

Table 6.11: Renewable Plant capacity

Power system - Total		
Capacity	1693	kW
Electricity	2817	MWh
Photovoltaic - 943 KW - Tracking system		
Capacity	943	kW
Electricity	1494	MWh
Wind Turbine - (5.2/s @ 10m)		
Capacity	750	kW
Electricity	1323	MWh

Table 6.12: Target of proposed Power Plant.

Terms	Electricity exported to gird (MWh)	Electricity export revenue ($)	GHG emission reduction (tCO_2)
Proposed case	2817	295,758	1388

6.6.5 GHG Emission

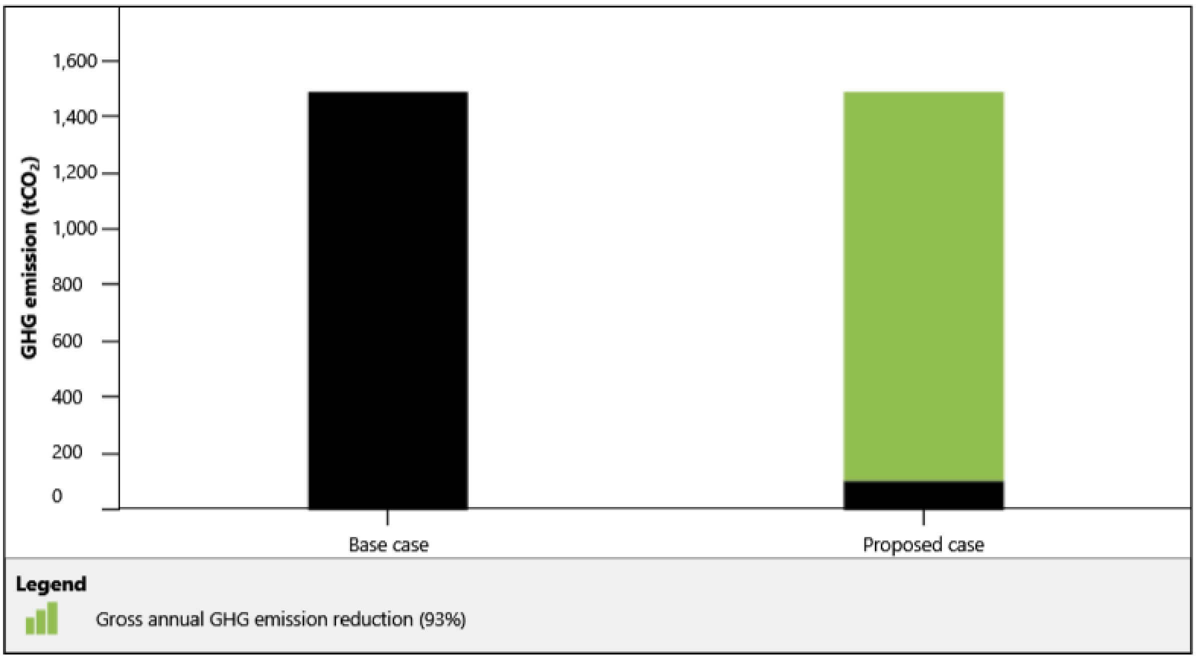


Figure 6.7: Graph of gross annual GHG emission reduction

1,388.1 tCO_2 is equivalent to 3,228.1

Barrels of crude oil not consumed

GHG emission		
Base case	1,492.6	tCO_2
Proposed case	104.5	tCO_2
Gross annual GHG emission reduction	**1,388.1**	**tCO_2**

Figure 6.8: GHG emission vs equivalent reserved crude oil

6.6.6 Financial Viability

Table 6.13: Finance parameters

General		
Inflation rate	%	3%
Discount rate	%	9%
Reinvestment rate	%	9%
Project life	yr	30%
Finance		
Debt. Ratio	%	70%
Debt.	$	1,251,287
Equity	$	536,266
Debt interest rate	%	7%
Debt term	yr	15
Debt payments	$/yr	137,385

Table 6.14: Annual revenue

Electricity export revenue		
Electricity exported to gird	MWh	2817
Electricity export rate	$/KWh	0.105
Electricity export revenue	$	295,758
Electricity export escalation rate	%	2%

GHG reduction revenue		
Net GHG reduction	tCO_2/yr	1319
Net GHG reduction - 30 yrs	tCO_2	39,561
GHG reduction credit rate	$/$tCO_2$	7.6
GHG reduction revenue	$	10,022
GHG reduction credit duration	yr	30
Net GHG reduction - 30yrs	tCO_2	39,561
GHG reduction credit escalation rate	%	3%

6.6.7 Cash Flow

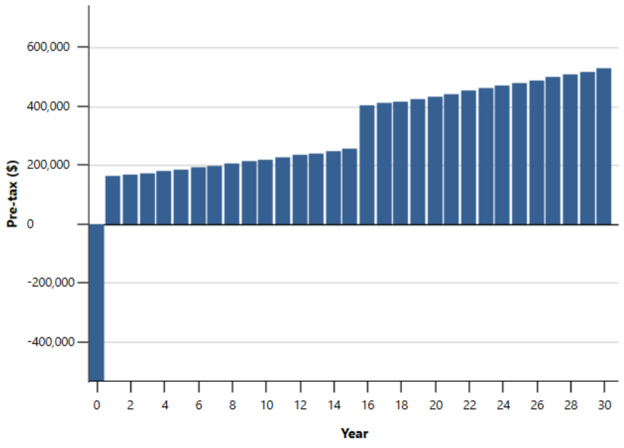


Figure 6.9: Graph of annual Pre-tax vs year

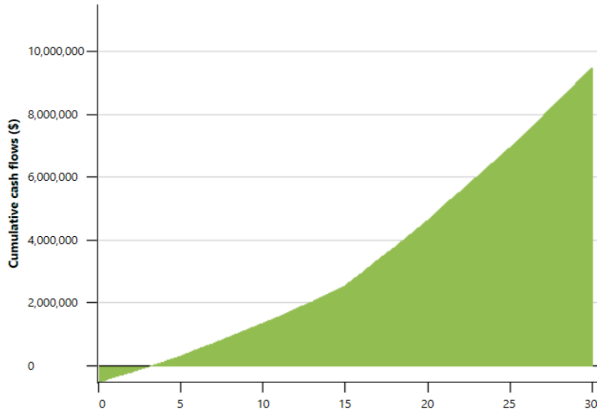


Figure 6.10: Graph of Cumulative cash flow vs year

6.6.8 Risk Analysis

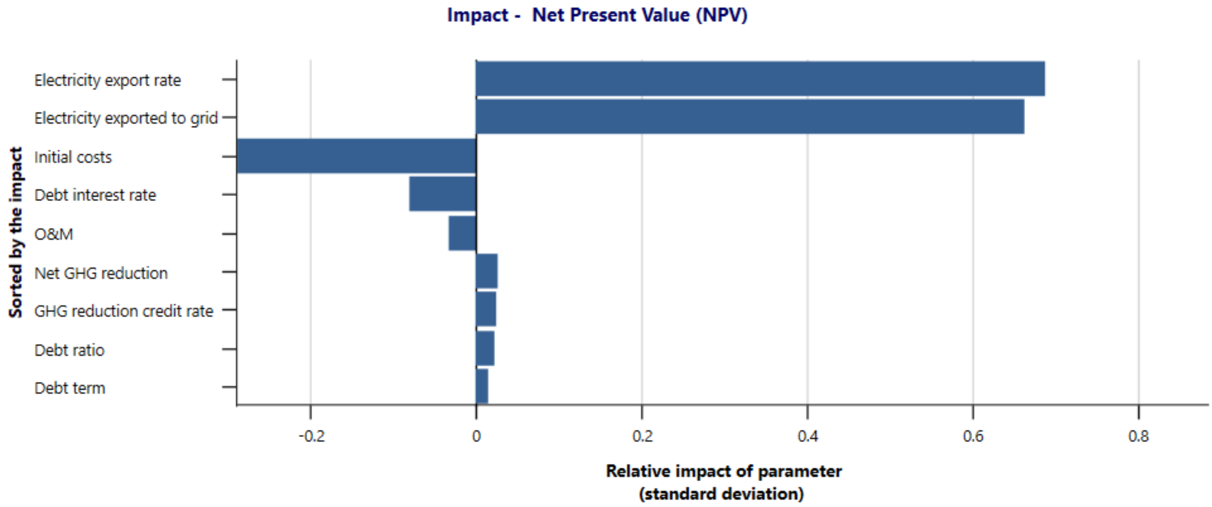


Figure 6.11: Impact of Net Present Value

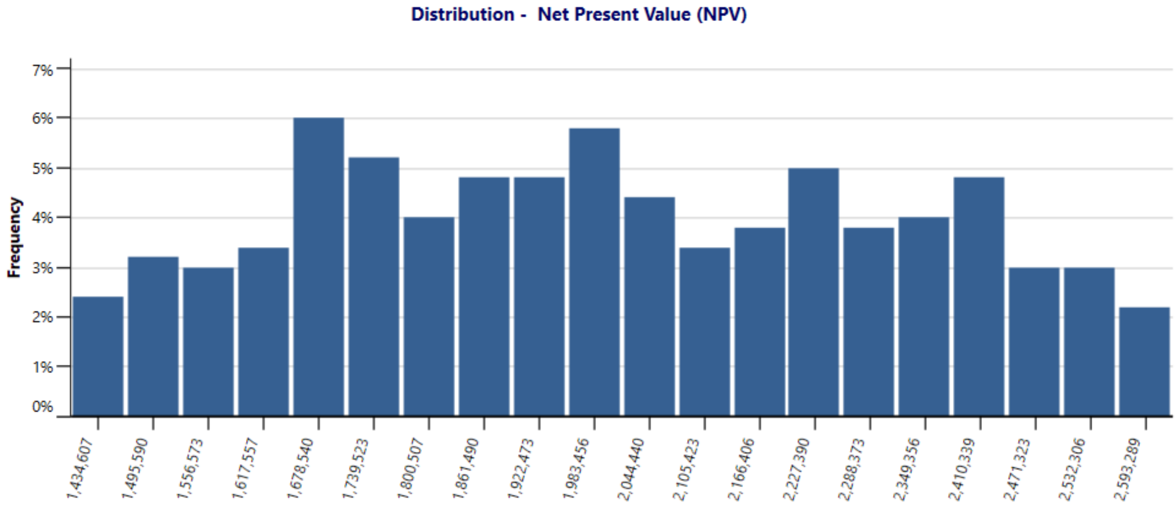


Figure 6.12: Distribution of Net Present Value

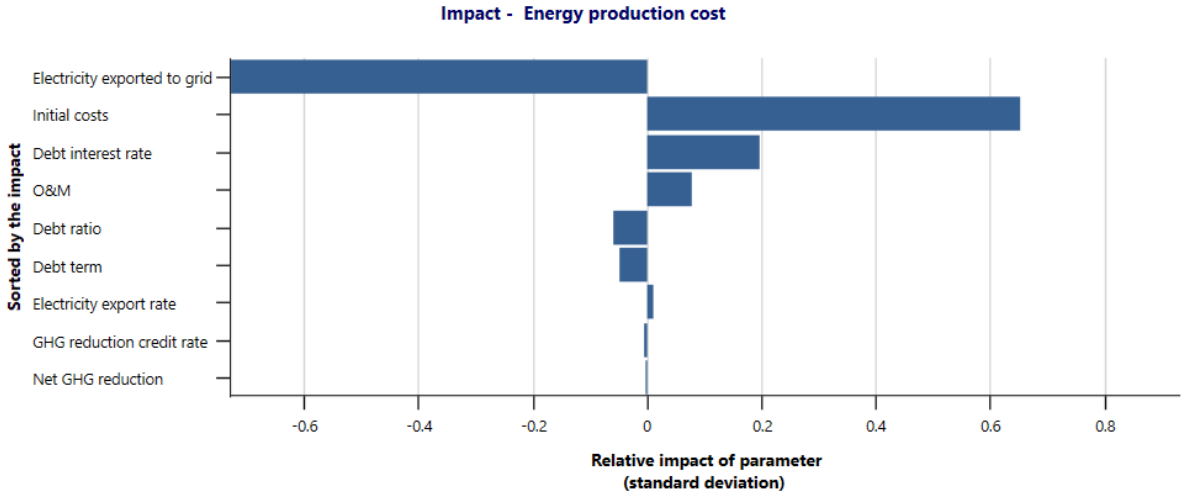


Figure 6.13: Impact of Energy production cost

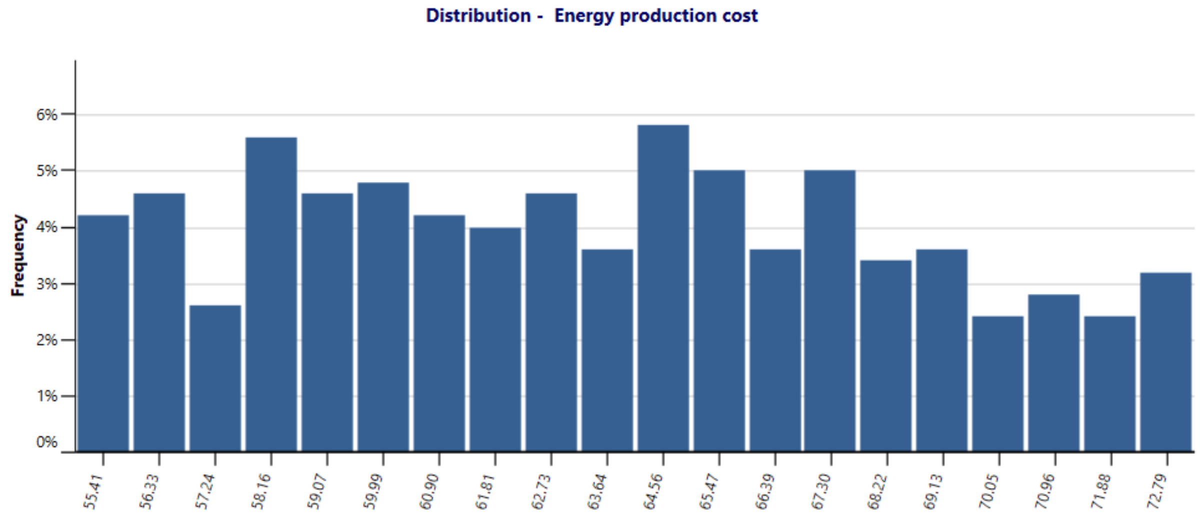


Figure 6.14: Distribution of Energy production cost

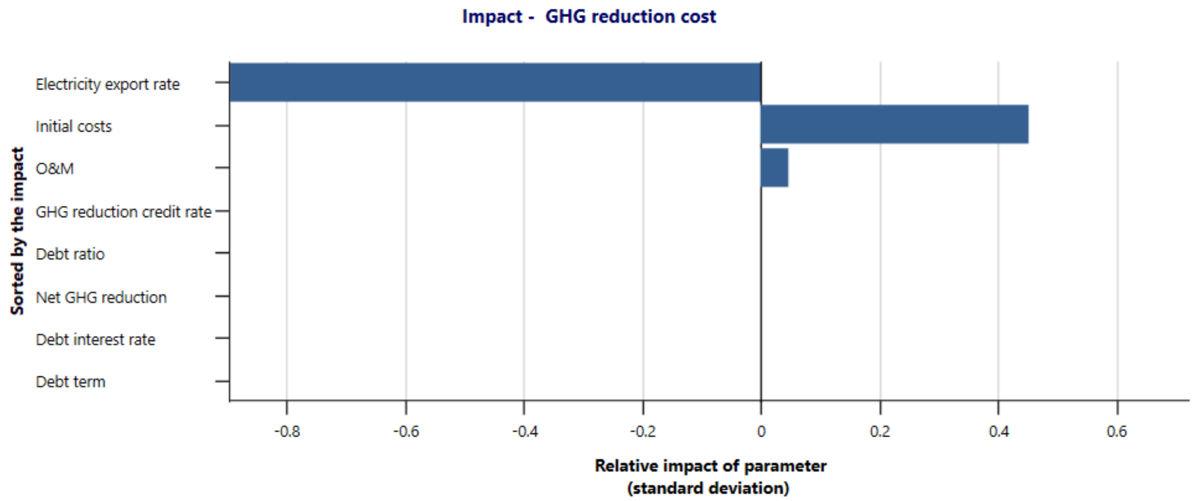


Figure 6.15: Impact of GHG reduction cost

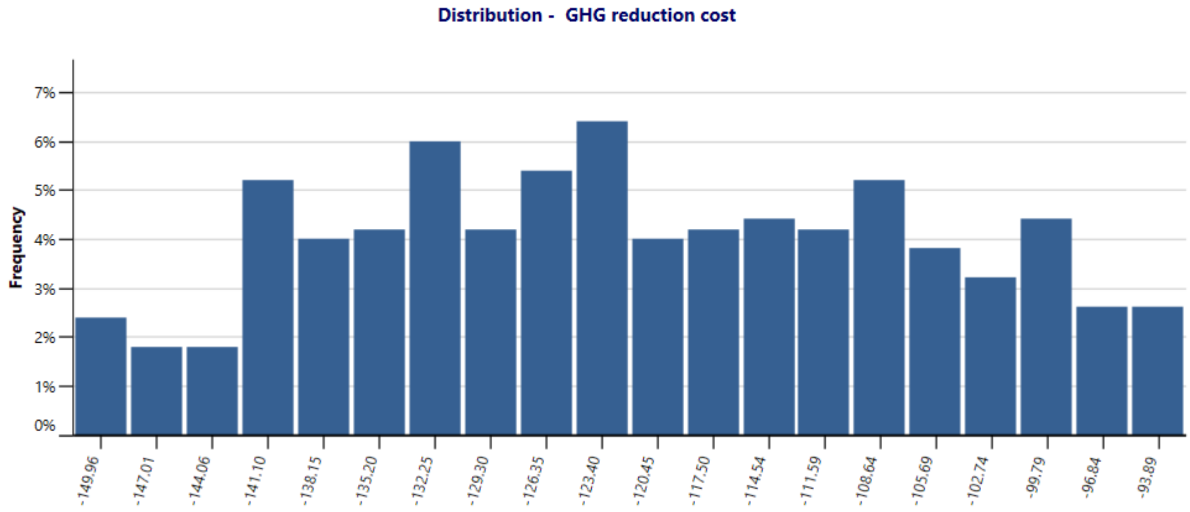


Figure 6.16: Distribution of GHG reduction cost

6.7 Chapter Summary

We may employ renewable energy in DG, where electricity from solar and wind power plants will not be reliant on fossil fuel-based power plants and will contribute to the distribution system's power loss reduction and high voltage profile.
Modeling and data analysis of solar energy have been accomplished, as a result of which the plant area and swept area has been determined, as well as the size of the power plant that must be built to provide the needed power to the DG. The PV module is designed to ensure the amount of PV module needed to get the desired power. PV and IV curves illustrated to extract saturated power and current.

According to RETScreen Expert's cost assessment, 2817 MW of energy is produced from a 1669 KW PV and Wind Power Plant, with an electricity export revenue of $ 295758 and a reduction in GHG emissions of 1388 tCO2. 1388 tCO2 is equivalent to 3228.1 barrels of crude oil not consumed.

Basically from this chapter, we can implement Uses of Solar and Wind Power in DG.

CHAPTER 7

CONCLUSION

7.1 Conclusion

Three different bus systems have been studied for DG implementation. The genetic algorithm was applied to three bus systems, yielding DG size, placement, and tie switch, when used to a distributed system, resulting in half of reduction of total power loss and a high voltage profile. Due to a shortage of fossil fuel, the unit price of fossil fuel-based power plants is rising nearly everyday. Carbon emissions, global warming, ozone layer degradation, climate change, rising sea levels, and other environmental issues are all caused by the use of fossil fuels. Renewable energy installation in DG has made significant solutions to this challenge available. Renewable energy sources have been investigated as a potential replacement for fossil-fuel-based power plants. This thesis paper's mathematical modeling of solar and wind has been installed, and a genetic algorithm has been employed to find the optimal solutions. In Chapter 5, the plant area for Solar and the swept area for Wind turbines were chosen for the development of renewable power plants based on the specified power by choosing the most feasible area. The PV module was designed using MATLAB Simulink, and the total number of modules was determined by choosing the required PV panel type and collecting the Solar Irradiance & Cell Temperature variables. Finally, Cost analysis using renewable energy in DG, Net present value, Cash flow, Energy production cost, GHG Reduction & Others Reduction Analysis has been done by RETScreen Expert.

7.2 Limitation

1. The analytical model is designed for single-DG installation, while multi-DG installation is not included.

2. The bulk of renewable energy, with the exception of solar and wind, was not included in the DG's evaluation.

3. Three alternative bus systems have been used to implement DG. However, in reality, there are various elements that are not considered in the study.

4. Although genetic algorithms were utilized to figure out the solution, alternative hybrid optimization techniques might have provided higher efficiency and accuracy.

5. Despite the fact that power storage is not included in DG deployment plans, it is critical to the grid's stability.

6. Solar and wind power plants cannot provide stable electricity as a backup to any grid.

7. The major emphasis of this thesis has been on sustainable energy, power loss reduction, and the High Voltage profile, but it is also vital to address DG installation and distribution network upgrade costs.

8. Solar and wind harmonics are not considered in the proposed model.

9. RETScreen Expert does not investigate expenses such as internal power plant costs, substation costs, labor costs, and many other costs that are averaged rather than taken in detail.

7.3 Future Scopes

1. To prevent power loss, Multi DG may be used.

2. All other renewable energy sources, such as hydro, tidal, biomass, and geothermal can be combined into DG.

3. In the future, another problem of reliability, durability, and stability may be explored.

4. For improved accuracy, try PSO or another hybrid optimization technique.

5. To assure sustainable electricity, the storage system may be linked to the grid.

6. Harmonics and noise cancellation in distribution networks may be analyzed, which will be critical in the deployment of distributed generation.

7. DG may be used to create a real-life cost analysis chart.

MATLAB CODES

Backward/Forward Analysis:

```
clc

clear all
close all
LD=load('linedata33bus.m'); %Line data
BD=load('loaddata33bus.m');  %Load data

Sbase=100; %Base Power (MVA)
Vbase=11; %Base Voltage (KV)
Zbase=(Vbase^2)/Sbase; %Impedance(ohm)

LD(:,4:5)=LD(:,4:5)/Zbase; %LD= Actual_LD/Base_LD | per unit
BD(:,2:3)=BD(:,2:3)/(1000*Sbase); %BD= Actual(Load Data)/Base (Load
Data) | per unit

N=max(max(LD(:,2:3)));

Sload=complex(BD(:,2),BD(:,3));
V=ones(size(BD,1),1);  %Initial voltage values
Z=complex(LD(:,4),LD(:,5));
Iline=zeros(size(LD,1),1);  %Current in lines
Iter=2000;

% The algorithm

for i=1:Iter
    %Backward Sweep

    Iload=conj(Sload./V);

    for j=size(LD,1):-1:1  %Start from the end of the feeder
        c=[];
        e=[];
        [c e]=find(LD(:,2:3)==LD(j,3));
        if size(c,1)==1
            Iline(LD(j,1))=Iload(LD(j,3));
        else
            Iline(LD(j,1))=Iload(LD(j,3))+sum(Iline(LD(c,1)))-
Iline(LD(j,1));
        end

    end

%Forward sweep

for j=1:size(LD,1)
    V(LD(j,3))=V(LD(j,2))-Iline(LD(j,1))*Z(j);
end
```

```
end

Voltage=abs(V);
Vangle=angle(V);

%%Losses
P=real(Z.*(Iline.^2)); %Power = z * I²
Q=imag(Z.*(Iline.^2));
```

Solar & Wind Data Calculation:

```
clc
clear all
close all
%Time                 Solar irradiance                   Wind speed
%(Monthly)            Data(W/m^2)                      Data(m/sec)
SW_Dt=[1                178.75                                4.5
    2                   203.33                                3.8
    3                   232.50                                3.5
    4                   242.92                                3.6
    5                   230.42                                4.3
    6                   175.00                                5.6
    7                   162.08                                5.8
    8                   162.50                                5.3
    9                   159.58                                4.2
    10                  178.75                                3.7
    11                  176.25                                4.1
    12                  175.42                                4.2];

Sr=SW_Dt(:,1); % Serial
S=SW_Dt (:,2); % solar
W=SW_Dt (:,3); % Wind

%% Solar Calculation
% P=AB u(t)
Power_Factor=0.95;
theta=acos(Power_Factor);
B=22.8/100;          % Efficiency (22.8%)
A=13.72;             % Area(m²)
S=sum(S);
S=S/12;

SL=A*B*S; %Solar Equation
SLP=((SL))/(1000); %Solar Power(kW) = Solar power/1000
SR= SLP
SVAr= SLP * sin(theta)

%% Wind Calculation

S_Area= 5959.86;
```

```
% S_Area= 5346;
disp('Wind Speed Result Choose input')
disp('For Wind Paper Parameters Press=0, For Rated Speed Press=1')
aa=input(' Press Value = ');
if aa==0
    V=sum(W); % W is wind data.
    V=V/12;
    V=V^3;
else
    V=14^3; % Rated Wind Speed: 14 m/s
end
AD= 1.17; % air density
BC=0.593; % Betz constant
WR= 0.5 * S_Area * V * AD * BC;
WRP= (WR)/1000;
WR= WRP
WRAr= WRP * sin(theta)
```

APPENDIX I
Solar & Wind Power Output Graph

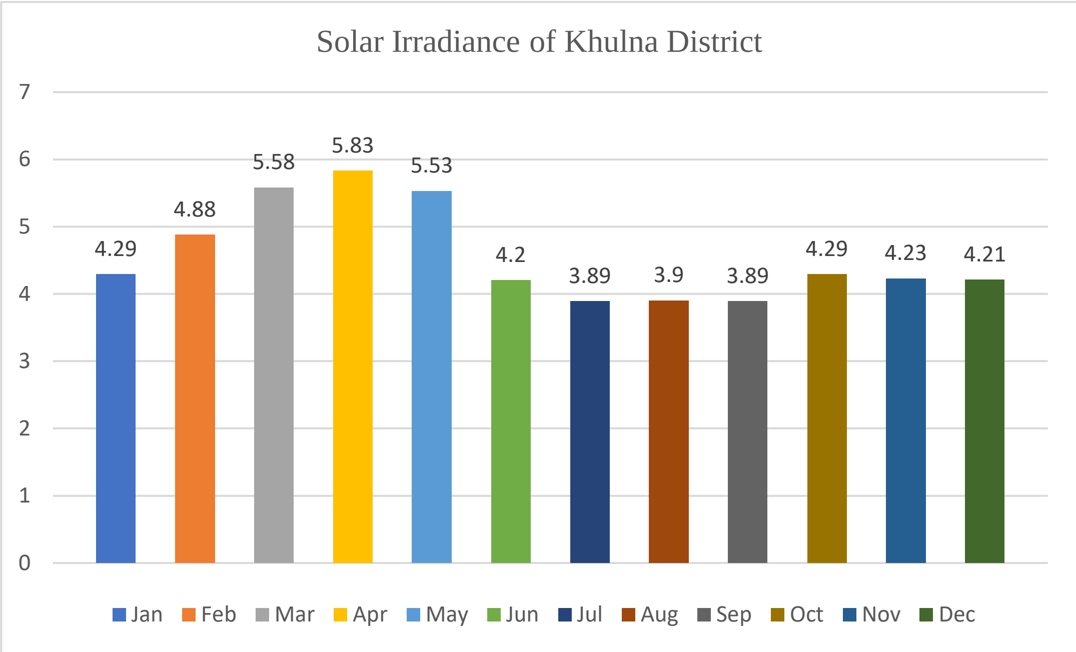


Figure 7.1: Annual Irradiance Graph of Khulna

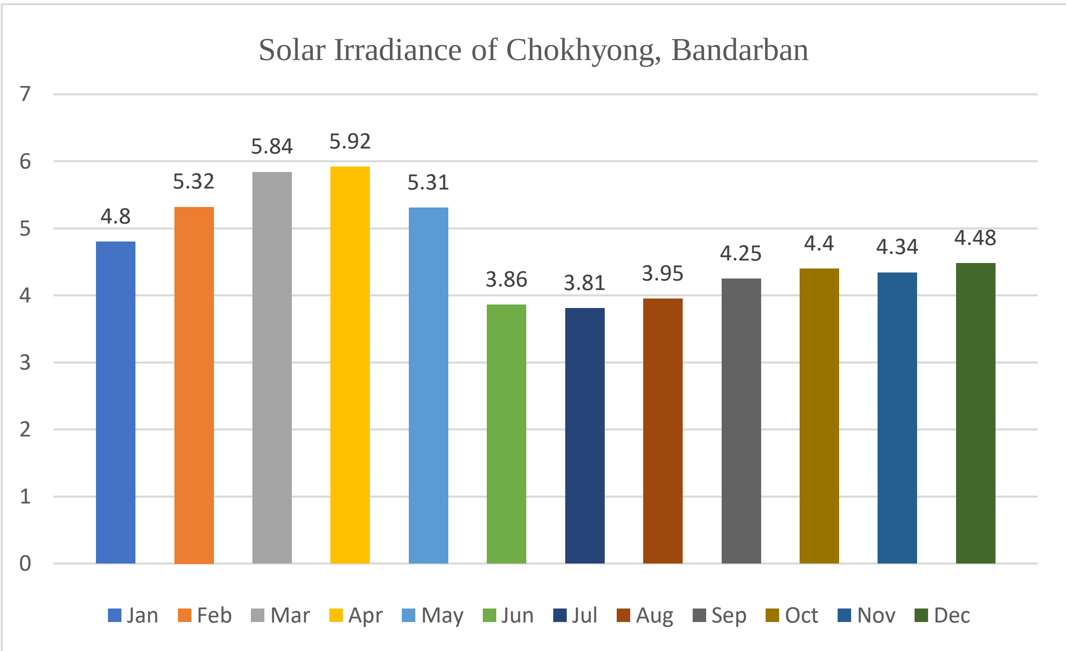


Figure 7.2: Annual Irradiance Graph of Bandarban

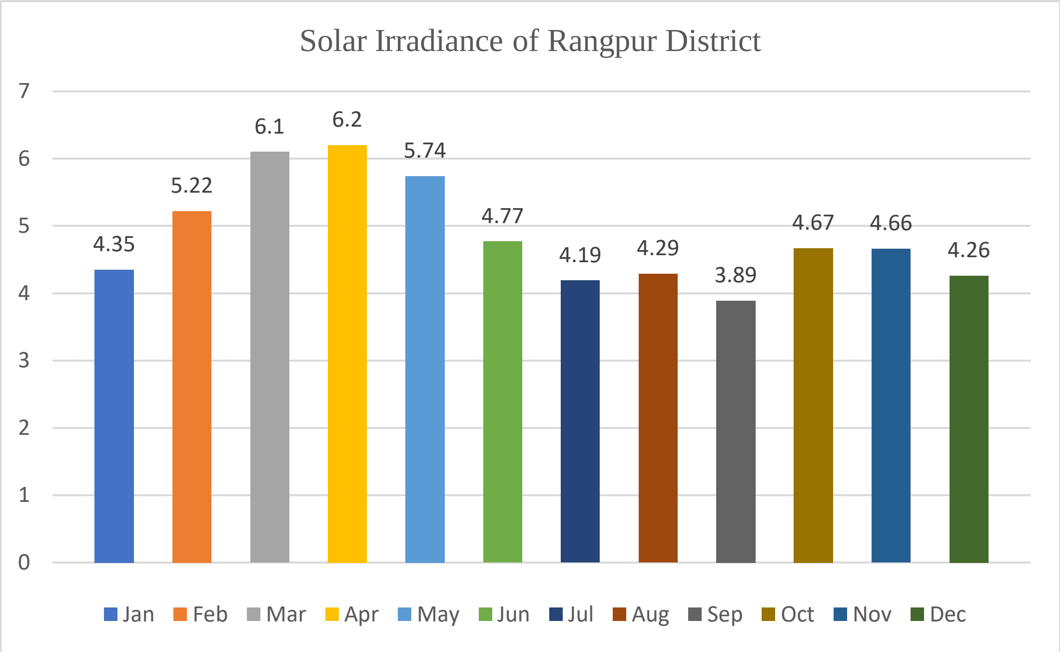


Figure 7.3: Annual Irradiance Graph of Rangpur

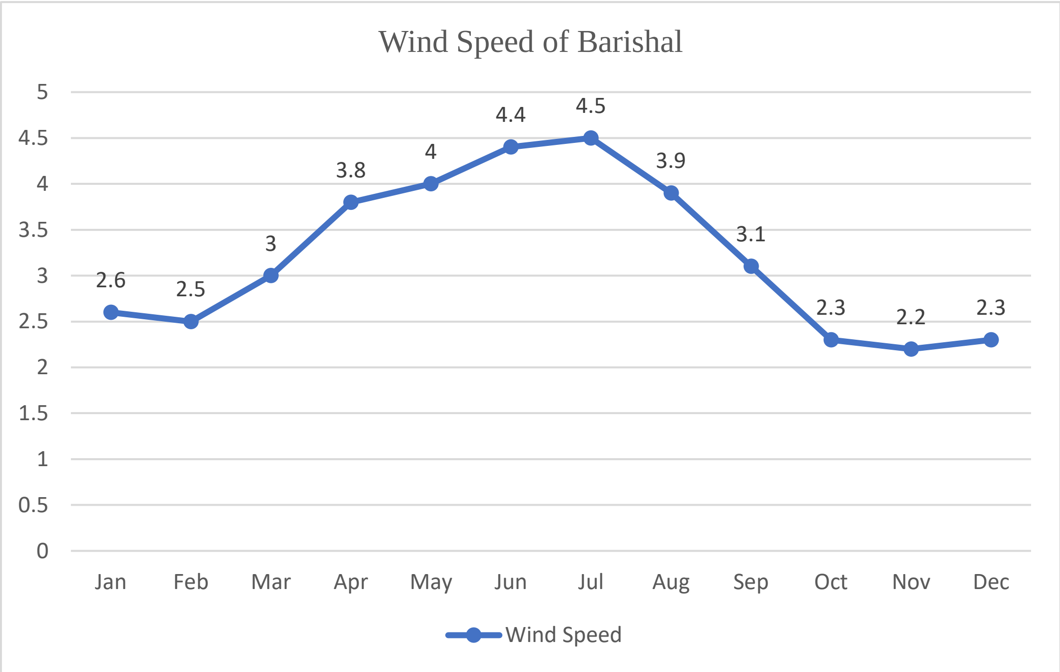


Figure 7.4: Annual Wind Speed Graph of Barishal

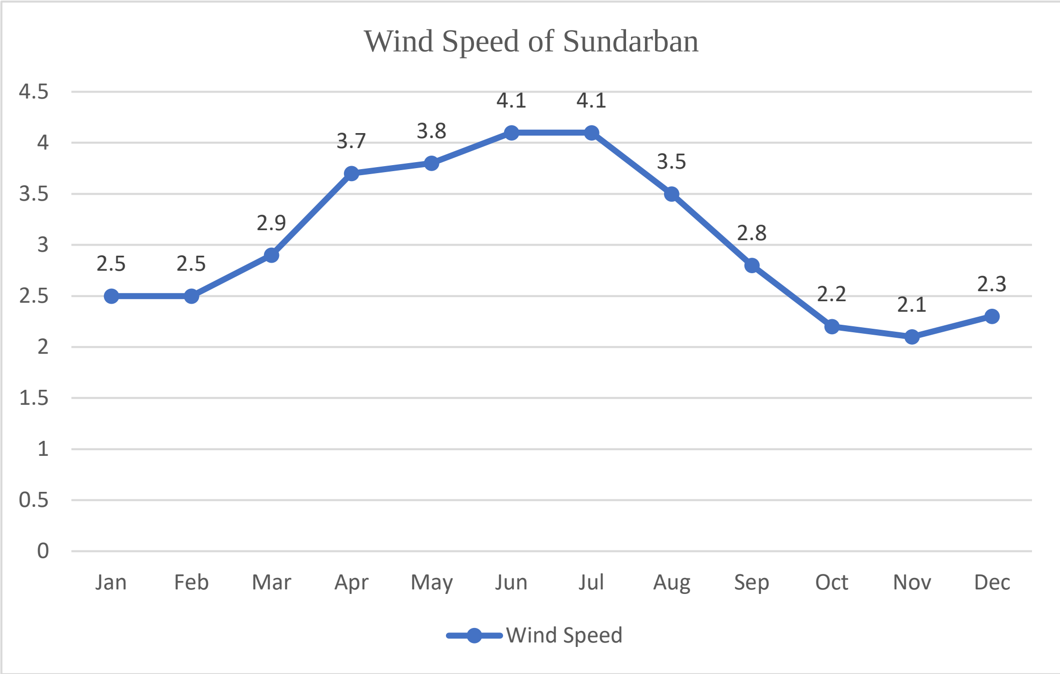


Figure 7.5: Annual Wind Speed Graph of Sundarban

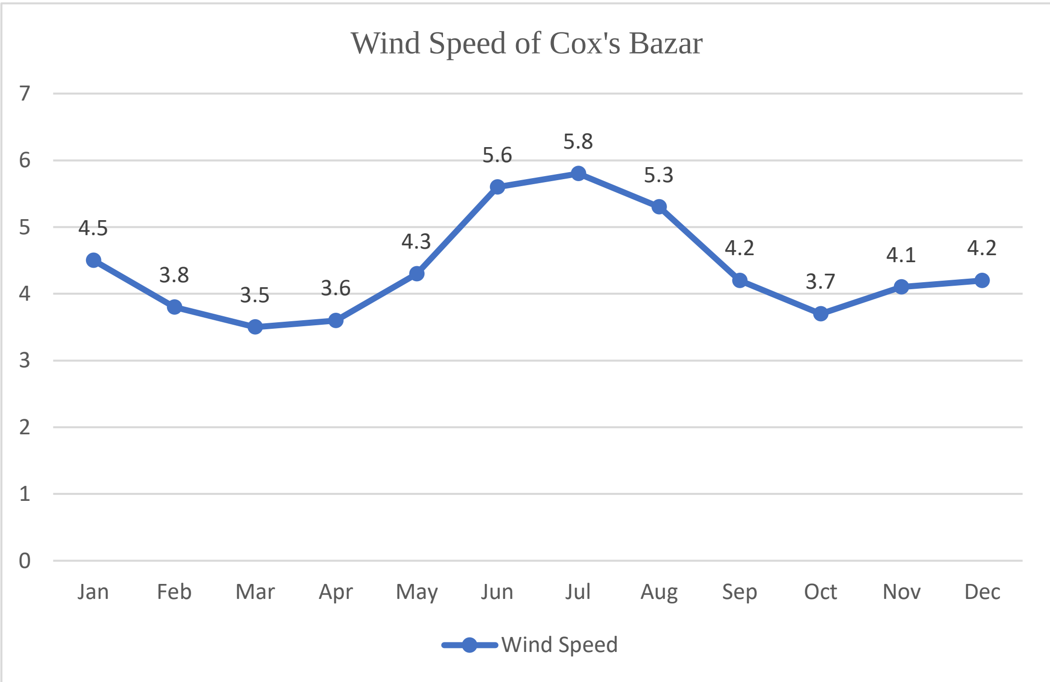


Figure 7.6: Annual Wind Speed Graph of Cox’s Bazar

APPENDIX II
Climate Data Collected by RETScreen Expert

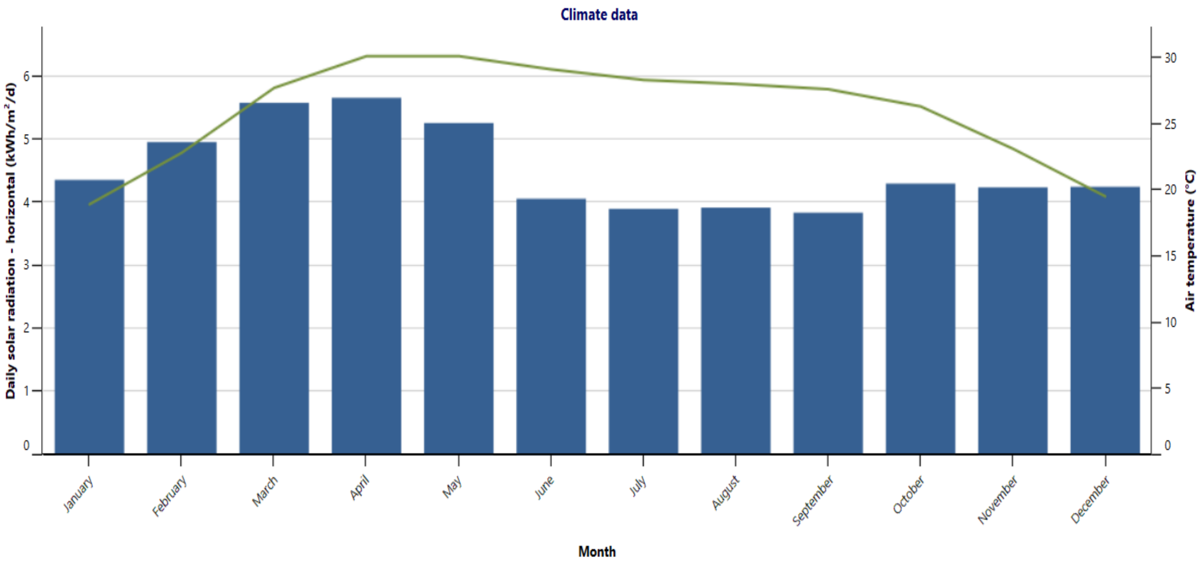


Figure 7.7: Annual Solar Irradiance Graph by NASA

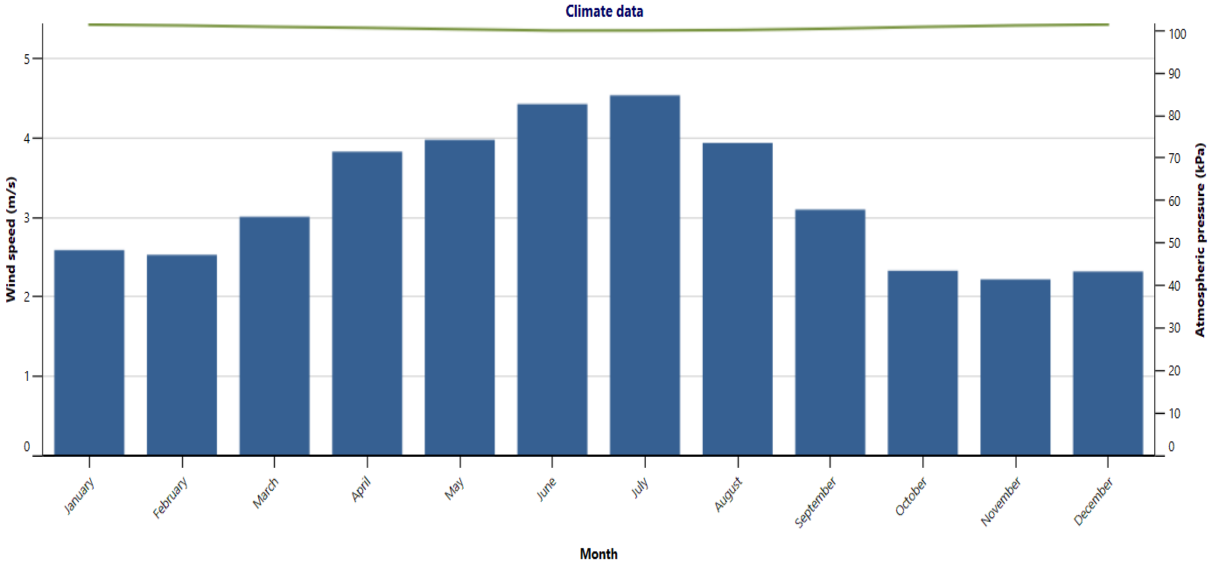


Figure 7.8: Annual Wind Speed Graph by NASA

APPENDIX III

Rooftop Mini Solar Plant Allocation (by google earth)

Figure 7.9: Rooftop Mini Solar Plant Allocation

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