ABSTRACT

The integration of renewable energy sources into the existing power grid has become a crucial aspect of energy management. The increasing demand for electricity and the need for reducing carbon emissions have forced power companies to shift towards cleaner and more sustainable energy sources. In this regard, the integration of solar photovoltaic (PV) systems and diesel generators (DGs) in a distributed network has gained significant attention.

The design of a distributed network with the integration of a DG set and PV system is aimed at achieving an efficient, reliable, and cost-effective power system. The incorporation of a DG set in the system provides backup power supply during peak demand or when there is an outage in the grid. On the other hand, a PV system generates power from renewable energy sources, which reduces carbon emissions and dependence on fossil fuels.

The design process involves identifying the optimal location and capacity of the DG set and PV system at each node in the network. The capacity of the PV system and DG set is determined by considering the load demand, available roof area, and local weather conditions. The installation of a PV system on the rooftop of buildings enables the generation of power in a distributed manner, reducing the load on the grid.

The performance of the system is analyzed before and after the installation of the DG set and PV system. The analysis is carried out by measuring the power quality parameters such as voltage, current, and power flow. The results show that the integration of a DG set and PV system in a distributed network leads to improved power quality, reduced carbon emissions, and lower energy costs.

In conclusion, the integration of a DG set and PV system in a distributed network is a promising solution for achieving sustainable energy management. The design process involves careful consideration of the location and capacity of the DG set and PV system to ensure maximum efficiency and reliability. The analysis of the system performance before and after installation demonstrates the benefits of incorporating renewable energy sources into the power grid. The adoption of this approach by power companies can lead to a more sustainable and resilient energy system.

INTRODUCTION

The design of distributed networks involves the planning and optimization of power systems that generate and distribute electricity to consumers. These systems can incorporate various sources of power generation, such as conventional power plants, renewable energy sources like solar and wind, and energy storage devices .One of the key challenges in designing distributed networks is to ensure that the system operates efficiently and reliably while meeting the energy demands of consumers. This involves careful consideration of factors such as load balancing, voltage control, and power quality, power flow among others.

To address these challenges, various techniques and algorithms have been developed. One such approach is the backward forward sweep method, which is used to calculate the power flow in distribution networks. This technique is particularly useful for designing networks that incorporate multiple sources of power generation, such as diesel generators and photovoltaic (PV) systems.

By using the backward forward sweep method, engineers can optimize the design of distributed networks to improve their efficiency, reliability, and resilience. The integration of diesel generators and PV systems, for example, can provide a flexible and reliable power supply that can meet the demands of consumers even in challenging conditions.

METHODOLOGY AND MATERIALS USED

Problem Statement:

The electrical maintenance section of the NIT Kurukshetra is planning for to install a new power distribution system in the campus. The source of the power will be the UHBVN substation near the Kirmach Road. It is connected to the substation at NIT Kurukshetra. The location of the buses and impedance of the conductor is given as:

Line Number	From Bus	To Bus	R(Ω)	X(Ω)
1	Substation UNBVN	Substation at NIT Kurukshetra	0.0922	0.0477
2	Substation at NIT Kurukshetra	Training and Placement Cell	0.493	0.2511
3	Training and Placement Cell	H4	0.366	0.1864
4	H4	H5	0.3811	0.1941
5	H5	H6	0.819	0.707
6	H6	H3	0.1872	0.6188
7	H3	H2	1.7114	1.2351
8	H2	H1	1.03	0.74
9	H1	H11	1.04	0.74
10	H11	H8	0.1966	0.065
11	H8	H7	0.3744	0.1238
12	H7	H9	1.468	1.155
13	H9	H10	0.5416	0.7129
14	H10	K. Chawla Hostel	0.591	0.526
15	K. Chawla Hostel	Alaknanda Bhawan	0.7463	0.545
16	Alaknanda Bhawan	Bhagirathi Bhawan	1.289	1.721
17	Bhagirathi Bhawan	Residential Area-1	0.732	0.574
18	Substation at NIT Kurukshetra	Admin Building	0.164	0.1565
19	Admin Building	Market	1.5042	1.3554
20	Market	Residential Area-2	0.4095	0.4784
21	Residential Area-2	Ground	0.7089	0.9373
22	H6	LHC block	0.203	0.1034
23	LHC block	MCA Deptt	0.2842	0.1447
24	MCA Deptt	SCOE	1.059	0.9337
25	SCOE	Applied mechanics block	0.8042	0.7006
26	Applied mechanics block	Civil Deptt	0.5075	0.2585
27	Civil Deptt	Electrical Deptt	0.9744	0.963
28	Electrical Deptt	Road lighting	0.3105	0.3619
29	Road lighting	Senate hall	0.341	0.5302
30	Training and Placement Cell	CSE Deptt	0.4512	0.3083
31	CSE Deptt	ECE Block	0.898	0.7091
32	ECE Block	Library	0.896	0.7011

The load connected and their location is given as:

Load	Location	Real Load (kW)	Reactive Load (kVAR)
L2	Substation at NIT Kurukshetra	100	60
L3	Training and Placement Cell	90	40
L4	H4	120	80
L5	H5	60	30
L6	H6	60	20
L7	H3	200	100
L8	H2	200	100
L9	H1	60	20
L10	H11	60	20
L11	H8	45	30
L12	H7	60	35
L13	H9	60	35
L14	H10	120	80
L15	K. Chawla Hostel	60	10
L16	Alaknanda Bhawan	60	20
L17	Bhagirathi Bhawan	60	20
L18	Residential Area-1	90	40
L19	Admin Building	90	40
L20	Market	90	40
L21	Residential Area-2	90	40
L22	Ground	90	40
L23	CSE Deptt	90	50
L24	ECE Block	420	200
L25	Library	420	200
L26	LHC block	60	25
L27	MCA Deptt	60	25
L28	SCOE	60	20
L29	Applied mechanics block	120	70
L30	Civil Deptt	200	600
L31	Electrical Deptt	150	70
L32	Road lighting	210	100
L33	Senate hall	60	40
Total		3715	2300

It is required to analyze to system performance and identify the active power flow, reactive power flow,voltage profile, current profile, losses occurring in the system.It is desired that the system voltage is kept as 1+0.05 pu. The losses of the system are to be kept at a minimum.

For power back-up the institute wants to install a Diesel Gen Set. Suggest a size and location of the DG set. Also, analyze the system performance before and after installation of the DG Set.The government wants to install roof top solar plant also. The capacity suggested is 1 MWp. It is to beinstalled on the building roofs on a distributed manner. Suggest the location and capacity (in MWp) at each node to be connected. Also, analyze the system performance before and after installation of theDG Set.(Consider the fixed capacity of the solar PV for the analysis. Do not consider the irradiance variation).Analyze the system performance before and after connecting DG Set and PV plant together.In case

the system performance goes down. Suggest the necessary changes in the system.

Approach:<u>Backward/Forward Sweep Power Flow</u>

- The Backward/Forward Sweep Power Flow(BFS) method is an iterative algorithm used to solve power flow problems in power systems.
- It is particularly useful for radial networks,where power flows in one direction from the substation to the load ,and there are no closed loops.
- The BFS method solve the power flow problem by breaking the system down into individual nodes and branches.
- It then applies a series of calculations to determine the voltage and power at each node.
- The method operates in two steps :
    - The forward sweep calculates the voltages at each node starting from the substation and moving towards the loads. At each node , the method calculates the current and power flowing through that node based on the voltages and loads connected to it .
    - The backward sweep calculates the voltages drop along each branch starting from the loads and moving towards the substation . At each branch , the method calculates the current and power flowing through that branch based on the voltage and loads connected to it.

The BFS method is an efficient way to solve radial networks as it only requires one iteration to converge to a solution. It also has the advantage of being relatively easy to implement in software, making it a popular method for power flow analysis in power system simulation software

The Ladder Iterative Method, also called Backward Forward Sweep method is an iterative technique used for load flow analysis in power systems. Here are the steps involved in this approach:

1. Assume initial voltage values for all buses in the power system. Usually, a starting voltage of 1.0 per unit is assumed for all buses.

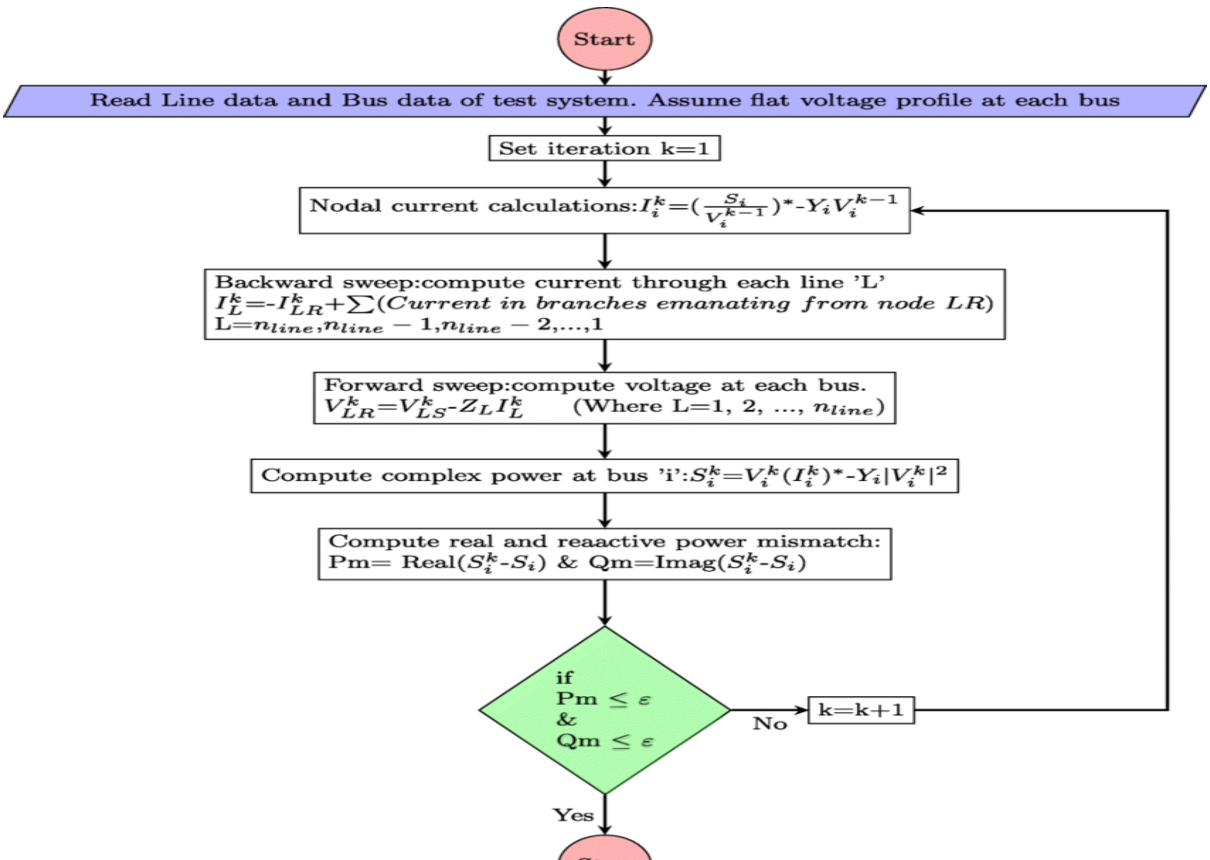
2. Calculate the power injections and admittances for all buses in the system. This involves using the load flow equations and the Y-bus matrix to determine the values of power injections and admittances for each bus.

3. Calculate the new voltage values for each bus in the system. This is done by using the power injections and admittances calculated in step 2, and the voltage values from the previous iteration.

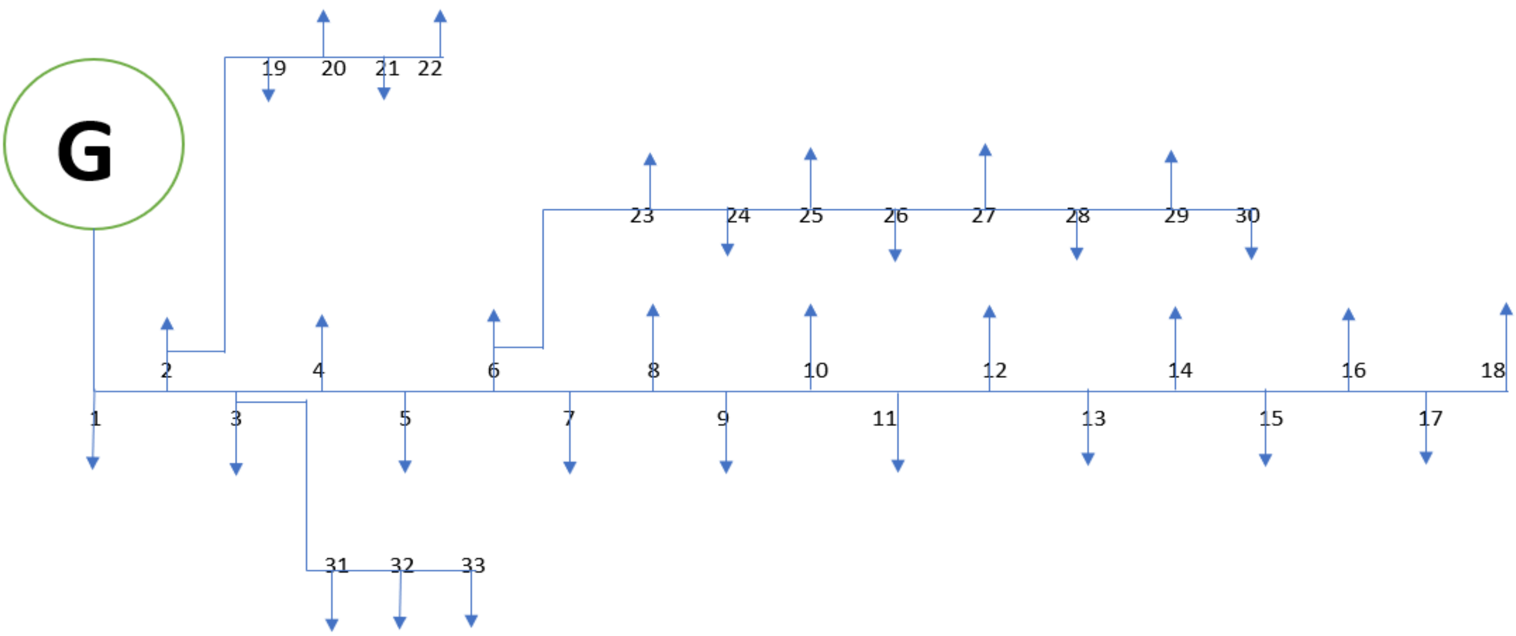
4. Check for convergence by comparing the new voltage values with the voltage values from the previous iteration. If the difference between the two sets of values is less than a pre-defined tolerance level, then the solution has converged. If not, repeat steps 2 and 3 until convergence is achieved.

5. Once convergence is achieved, calculate the line flows and losses in the system. This involves using the power flow equations and the Y-bus matrix to determine the line flows and losses for each line in the system.

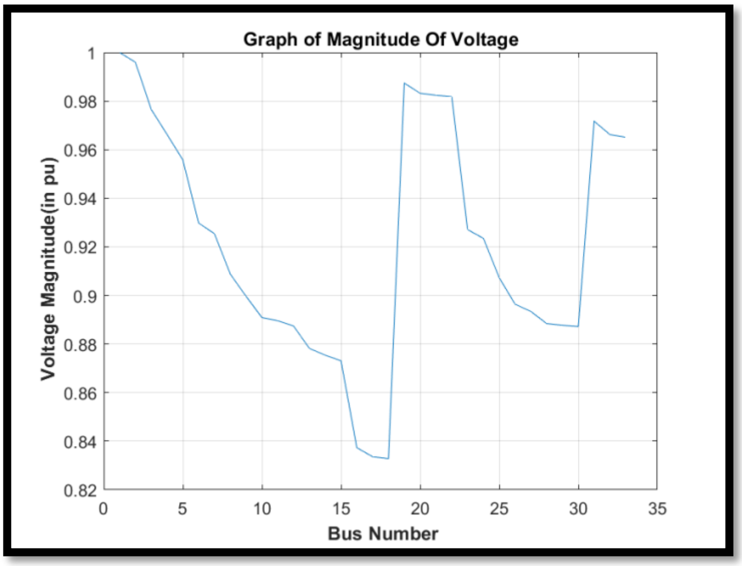
Overall, the Ladder Iterative Method is an effective approach to load flow analysis in power systems, and is widely used in the industry.



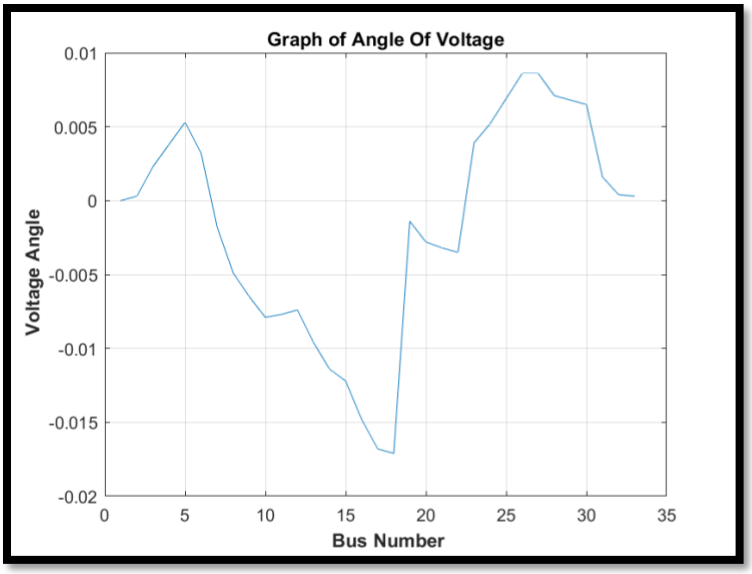
SINGLE LINE DIAGRAM



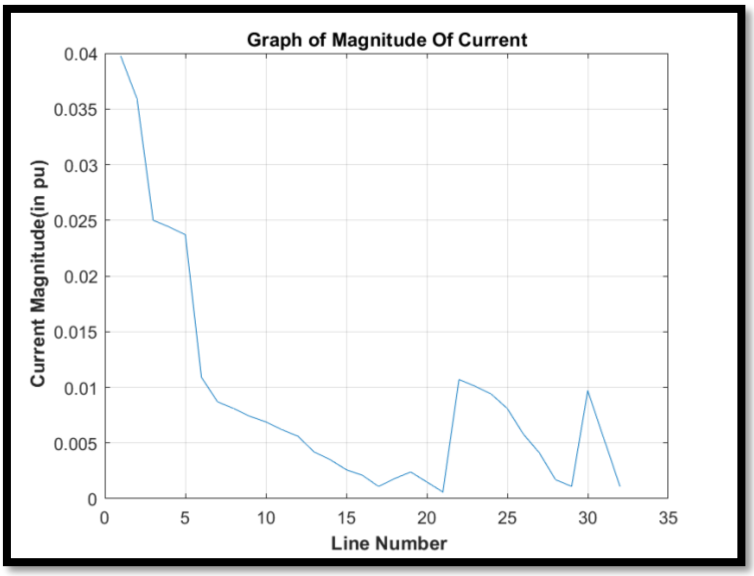
Voltage Magnitude



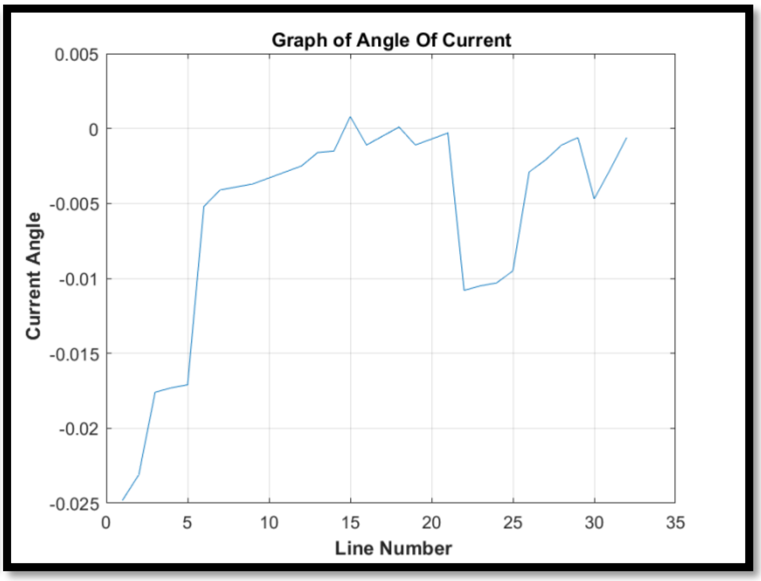
Voltage Angle



Current Magnitude



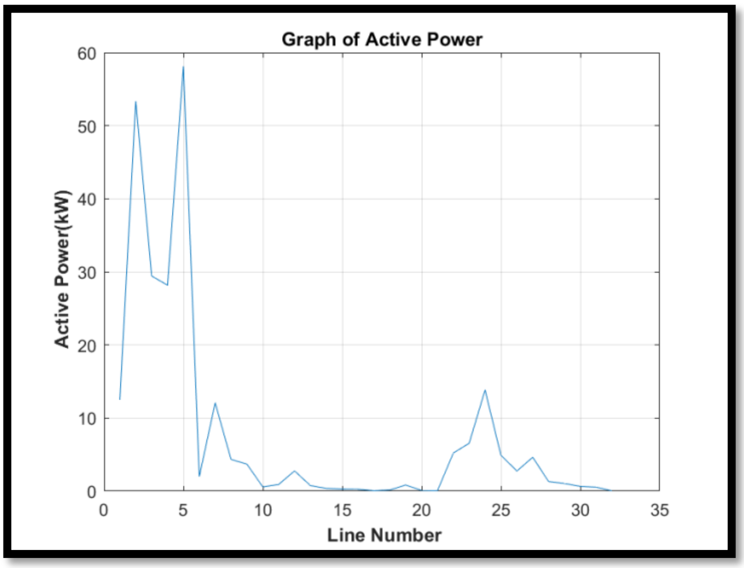
Current Angle



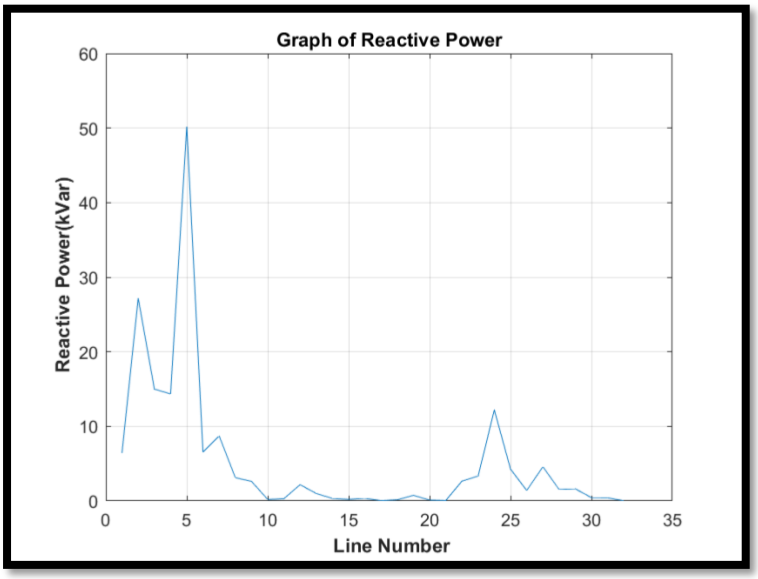
Analysis of System Performance

- From the obtained Voltage Profile,Current Profile and Power Profile,we can determined the total losses in the system.
- Total Active Power Loss=252.04 kW
- Total Reactive Power Loss=172.410 kVar

Active Power



Reactive Power



LOAD FLOW ANALYSIS(WITH DIESEL GENERATOR)

The installation of a DG set can lead to several changes in the system parameters, such as:

1. Voltage profile: The voltage profile of the system may improve after the installation of a DG set. This is because the DG set can provide reactive power support, which helps to maintain voltage levels within the acceptable limits.

2. Power factor: The power factor of the system may improve after the installation of a DG set. This is because the DG set can provide reactive power support, which helps to reduce the reactive power demand from the grid.

3. Frequency: The frequency of the system may improve after the installation of a DG set. This is because the DG set can provide additional power to the system, which helps to balance the supply and demand and maintain the frequency within the acceptable limits.

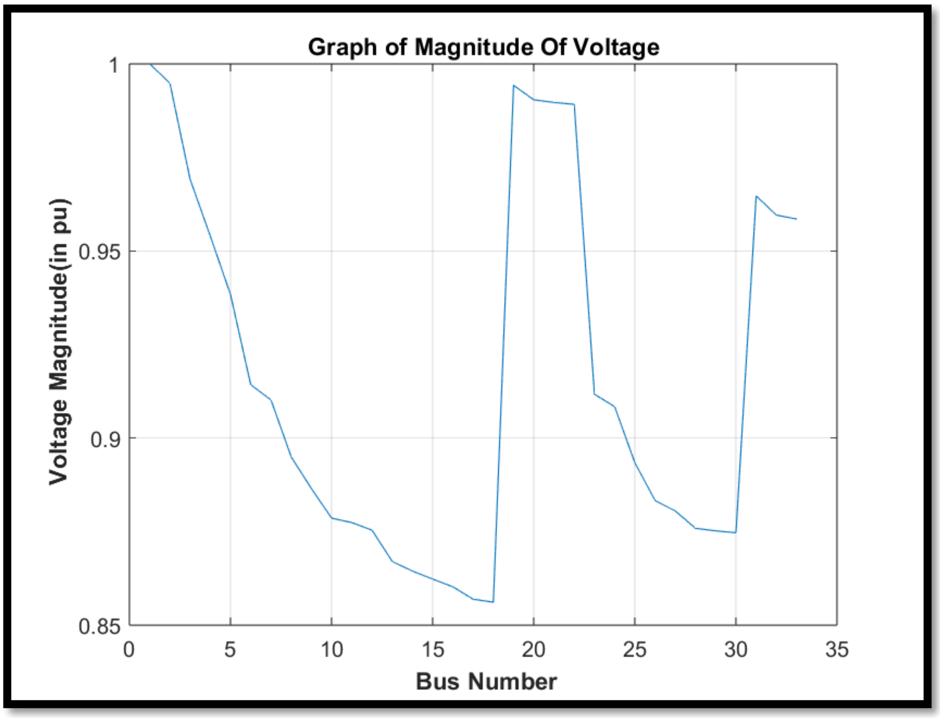
4. Power quality: The power quality of the system may improve after the installation of a DG set. This is because the DG set can provide clean and stable power to the system, which can help to reduce the levels of harmonic distortion and other power quality issues.

Overall, the installation of a DG set can have a positive impact on the system parameters and help to improve the overall reliability and stability of the power distribution system

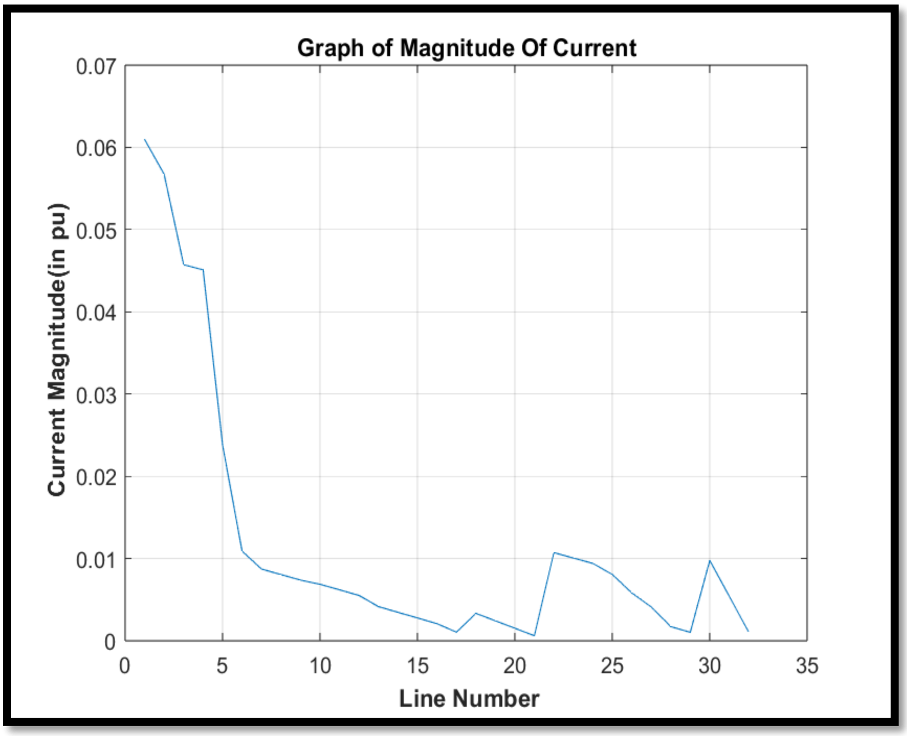
SYSTEM PERFORMANCE AFTER INSTALLING THE DG:

- The optimal location of the diesel generator to be installed is at the Bus No. 6 (H6) having the size of **2 MW**
- This will leads to the improvement of the pu voltage drop across each line.
- Also after installing the Diesel Generator, Power Profile of the system improves hence the losses also decreases thus leading to more stability.

Voltage Profile



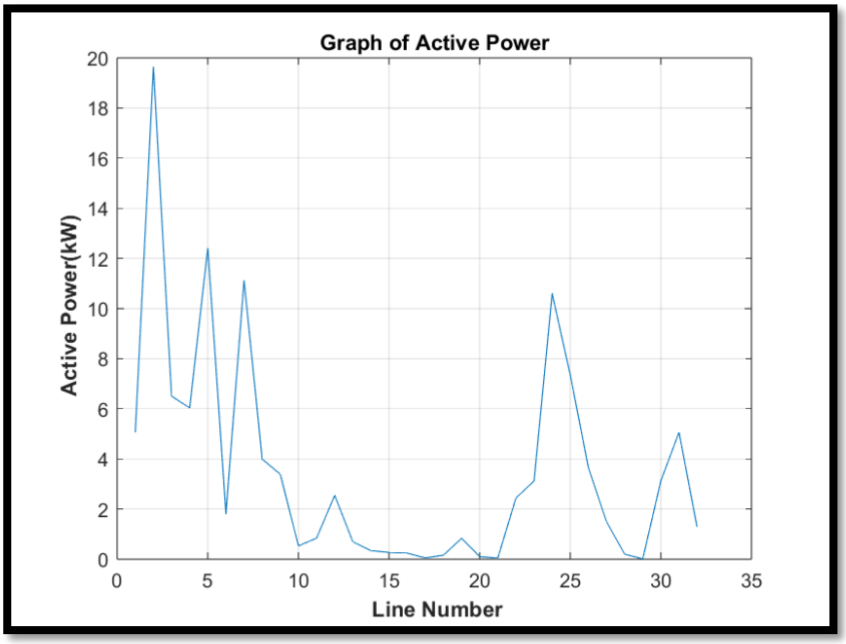
Current Profile



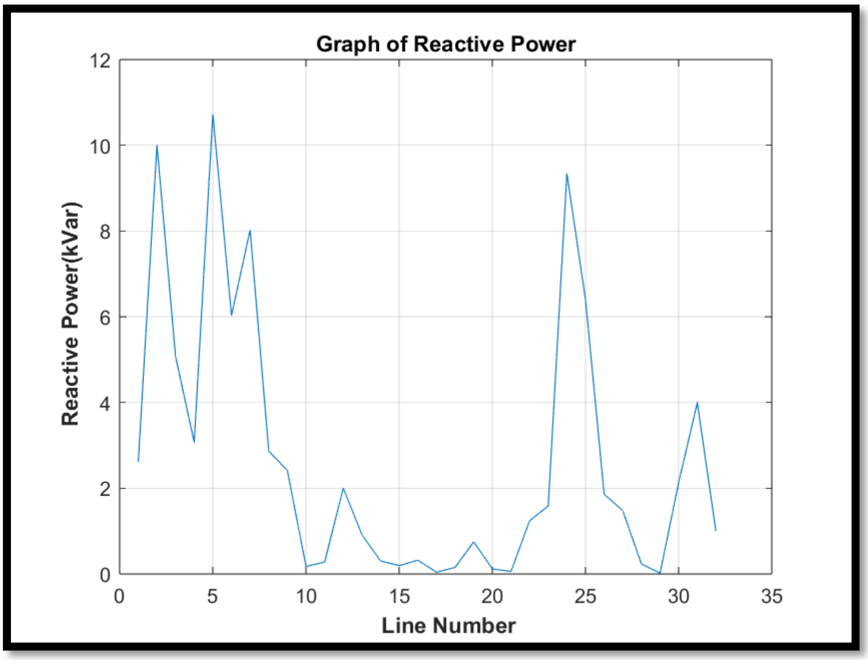
Analysis of System Performance

- From the obtained Voltage Profile,Current Profile and Power Profile,we can determined the total losses in the system.
- Total Active Power Loss=114.959 kW
- Total Reactive Power Loss=83.662 kVar

Active Power Flow



Reactive Power Flow



LOAD FLOW ANALYSIS(WITH SOLAR PLANT)

After the installation of PV cells in a distributed network, the system parameters can change in the following ways:

1. Reduced Dependency on Grid: The distributed network with integrated PV cells can generate electricity locally, reducing the dependency on the grid. This can result in a reduction in the amount of electricity purchased from the grid, leading to cost savings.

2. Reduction in Emissions: The use of PV cells can significantly reduce the emissions associated with conventional power generation, which can lead to improvements in air quality and a reduction in greenhouse gas emissions.

3. Increased Efficiency: The integration of PV cells can also increase the overall efficiency of the distributed network. PV cells can generate electricity during the day, which can be used to power loads directly, or to charge batteries for use during times when the sun is not shining. This can reduce the need for diesel generators and increase the overall efficiency of the system.

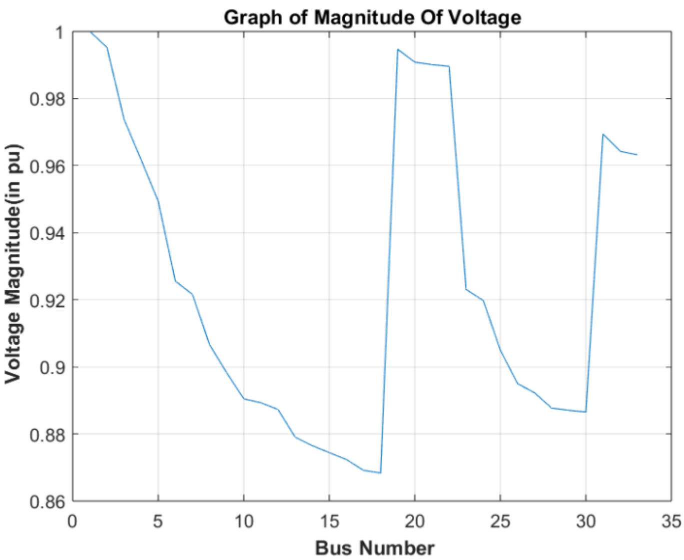
4. Improved Reliability: The use of PV cells can also increase the reliability of the distributed network. Since PV cells can generate electricity locally, the system can continue to operate even during grid outages or other disruptions. This can help to improve the overall reliability of the system and reduce downtime.

SYSTEM PERFORMANCE AFTER INSTALLING THE SOLAR PLANT

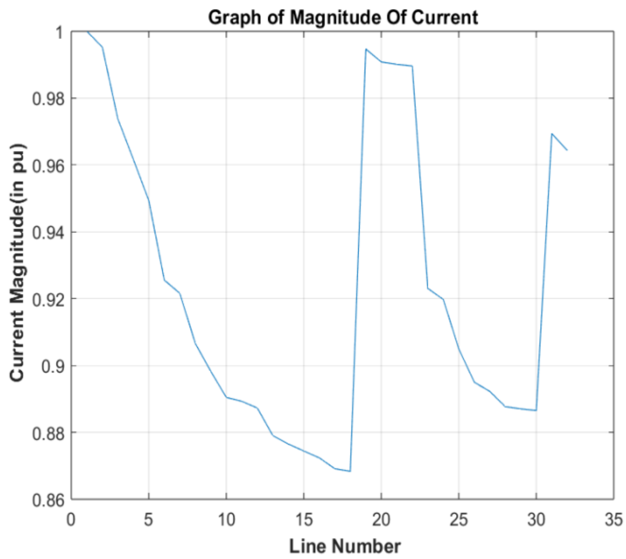
- We have installed the Solar Plants having total capacity be 1 MW and have installed at different location in distributed manner .
- This will leads to the improvement of the pu voltage drop across each line.

Also after installing the Solar Plant at different bus, Power Profile of the system improves hence the losses also decreases thus leading to more stability.

Voltage Profile



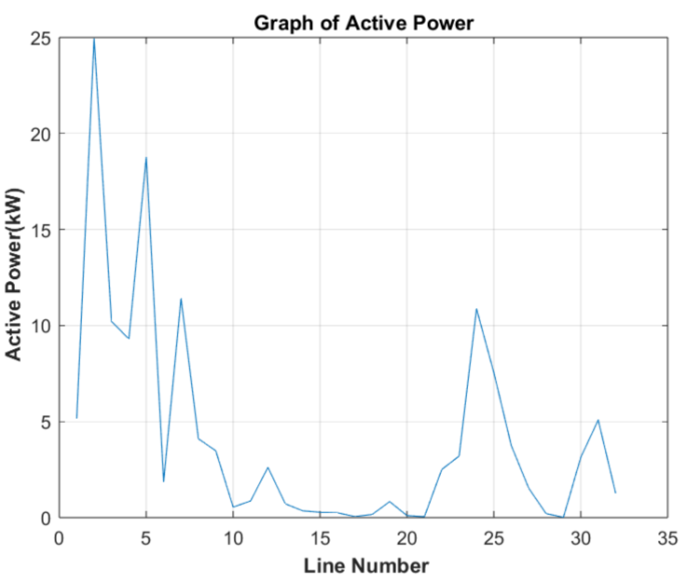
Current Profile



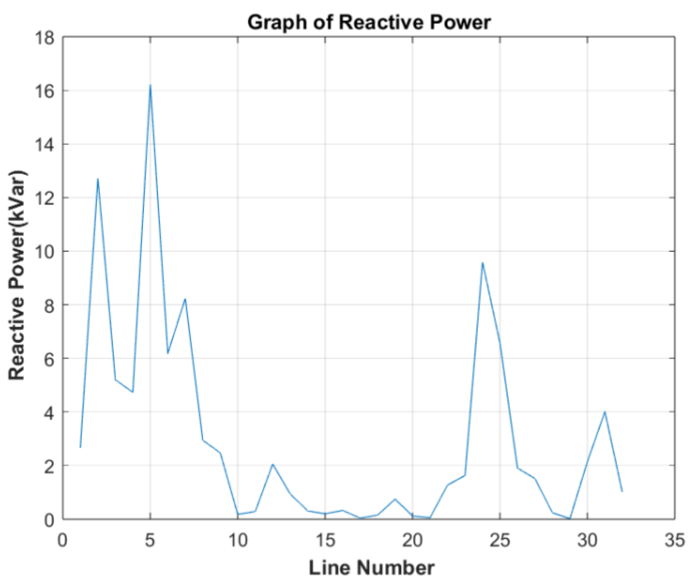
- From the obtained Voltage Profile,Current Profile and Power Profile,we can determined the total losses in the system.

- Total Active Power Loss=135.163 kW
- Total Reactive Power Loss=96.679 kVar

Active Power Flow



Reactive Power Flow



LOAD FLOW ANALYSIS (WITH SOLAR PLANT AND DIESEL GENERATOR)

The integration of PV cells and a diesel generator in a distributed network can have significant impacts on the system parameters. Here are four points on how these changes occur:

1. With the installation of PV cells, the system's reliance on the grid reduces, leading to a decrease in the total energy consumption from the grid.

2. The addition of a diesel generator provides a backup source of energy in case of a grid failure, ensuring continuity of power supply.

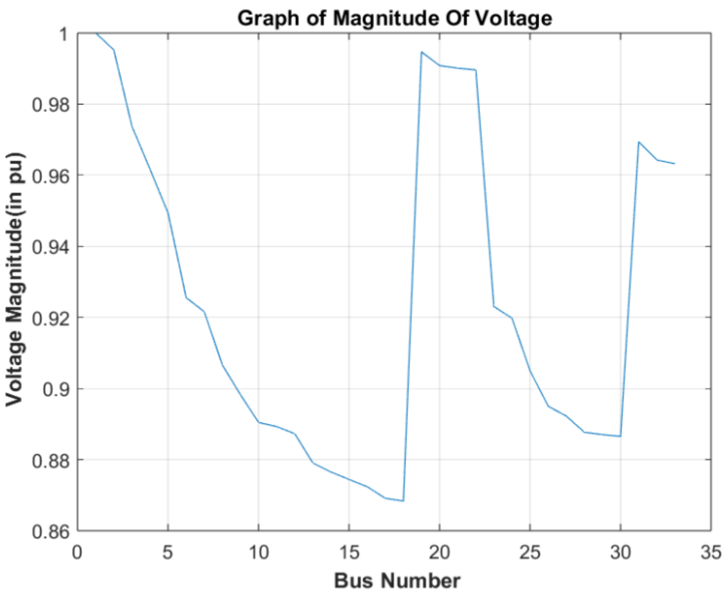
3. Integration of PV cells and diesel generators result in a reduction of carbon footprint and a decrease in greenhouse gas emissions, contributing to environmental sustainability.

4. The implementation of a distributed network with a combination of renewable and non-renewable energy sources results in better energy management and greater control over the system.

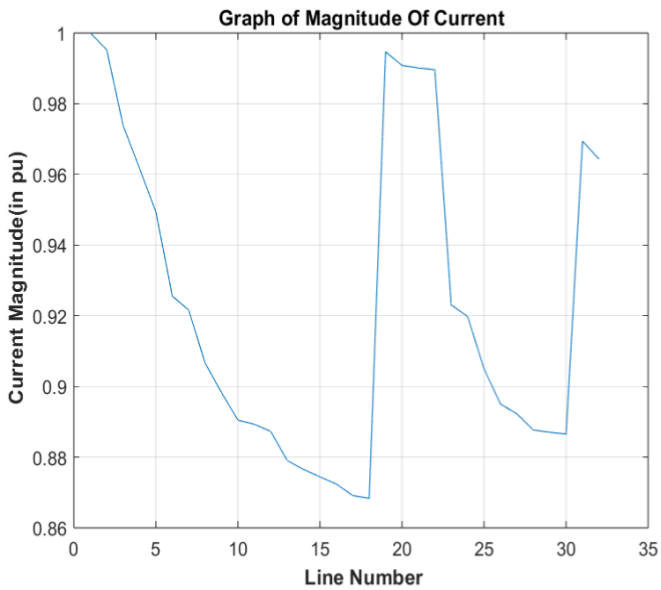
SYSTEM PERFORMANCE AFTER INSTALLING THE SOLAR PLANT AND DG

- We have installed the Solar Plants having total capacity be 2 MW and Diesel Generator having total capacity be 2 MW have installed at three locations.
    - Bus 2(Substation at NIT Kurukshetra) **0.5MW(SOLAR)**
    - Bus 3(Training and Placement Cell) **0.5MW(SOLAR)**
    - Bus 6(H6) **2MW(2MW-DG)**
- This will leads to the further improvement of the pu voltage drop across each line.
- Also after installing the Diesel Generator and Solar Plants simultaneously, Power Profile of the system improves hence the losses further decreases thus leading to more stability and more performance.

Voltage Profile

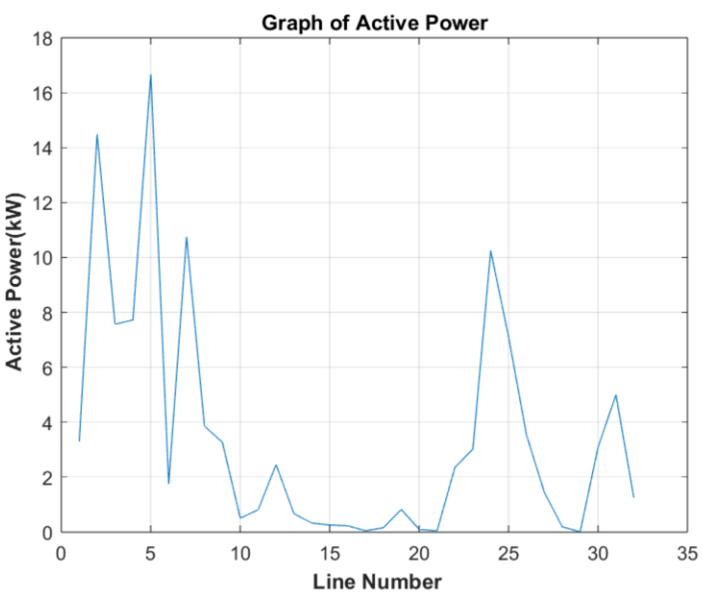


Current Profile

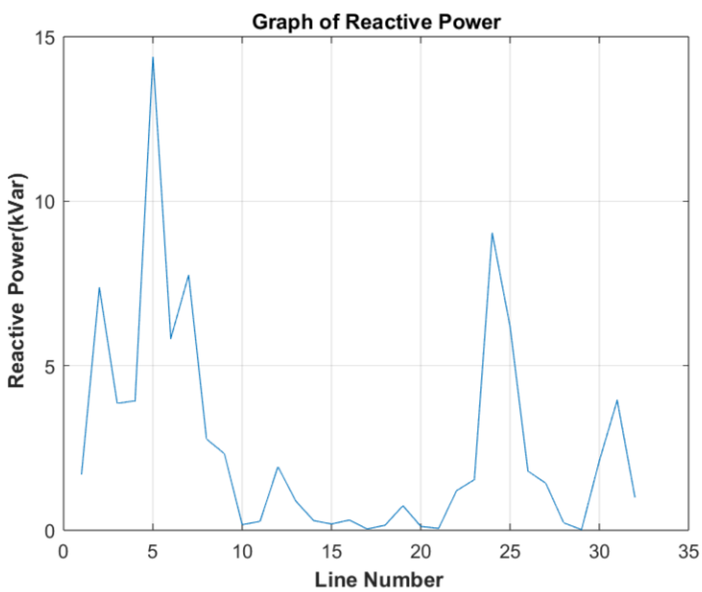


- From the obtained Voltage Profile,Current Profile and Power Profile,we can determined the total losses in the system.
- Total Active Power Loss=113.096 kW
- Total Reactive Power Loss=83.58 kVar

Active Power Flow



Reactive Power Flow



CONCLUSION

The integration of a diesel generator and photovoltaic cells in a distributed network can provide significant benefits in terms of cost savings, energy efficiency, and sustainability. In this study, a backward-forward sweep method was used to analyze the performance of a distributed network with the integration of a diesel generator and PV cells.

The results showed that the addition of PV cells can significantly reduce the reliance on the diesel generator, resulting in a decrease in fuel consumption and carbon emissions. Additionally, the integration of PV cells and a diesel generator can provide a reliable and resilient power supply by ensuring uninterrupted power supply in the event of a grid outage.

Furthermore, the location and capacity of PV cells were optimized to ensure maximum energy production and distribution efficiency. The backward-forward sweep method provided a robust analysis of the network's performance and allowed for accurate optimization of system parameters.

Overall, the integration of PV cells and a diesel generator in a distributed network can offer a reliable, cost-effective, and sustainable energy solution. This study demonstrates the effectiveness of the backward-forward sweep method for the design and optimization of distributed networks with multiple power sources.

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- M. A. Adhikari and M. R. Islam, "Design and performance analysis of a hybrid power system using HOMER for off-grid electrification in Bangladesh," Renewable and Sustainable Energy Reviews
- B. K. Gupta and D. Singh, "Design and simulation of a hybrid power system using PV, wind, and diesel generator for a remote telecom station," International Journal of Renewable Energy Research

BFS CODE

```
LineData=load('linedata33bus.m');   %Line Data
BusData=load('busdata33bus.m')      %Bus Data

Sbase=100;     %MVA
Vbase=11.5;    %KV
Zbase=(Vbase^2)/Sbase;

LineData(:,4:5)=LineData(:,4:5)/Zbase;
BusData(:,2:3)=BusData(:,2:3)/(Sbase*1000);

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

Sload=complex(BusData(:,2),BusData(:,3));

%Initial Voltage Values
V=ones(size(BusData,1),1);

Z=complex(LineData(:,4),LineData(:,5));

% Current in each Line
Iline=zeros(size(LineData,1),1);

iter=2000;
```

```
for i=1:iter

    %BackWard Sweep
    Iload=conj(Sload./V)

    for j=size(LineData,1):-1:1
        c=[];
        e=[];
        [c e]=find(LineData(:,2:3)==LineData(j,3));

        % if c has only one value that means j is a beginning or ending bus
        if size(c,1)==1
            Iline(LineData(j,1))=Iload(LineData(j,3));
        else
            Iline(LineData(j,1))=Iload(LineData(j,3))+sum(Iline(LineData(c,1)))-Iline(LineData(j,1));
        end
    end

    %Forward Sweep
    for j=1:size(LineData,1)
        V(LineData(j,3))=(V(LineData(j,2))-Iline(LineData(j,1))*Z(j));
    end
end

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

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

VOLTAGE AND CURRENT PROFILE

```
clear all
% Reading the data from XLSX
BusNumber=xlsread(['C:\Users\Shivansh Kumar Jha\OneDrive\Desktop\' ...
    'DSAA PROJECT\Data Values\VoltageProfile.xlsx'],'A5:A37');
VoltageMagnitude=xlsread(['C:\Users\Shivansh Kumar Jha\OneDrive\Desktop\' .
    'DSAA PROJECT\Data Values\VoltageProfile.xlsx'],'C5:C37');
VoltageAngle=xlsread(['C:\Users\Shivansh Kumar Jha\OneDrive\Desktop\' ...
    'DSAA PROJECT\Data Values\VoltageProfile.xlsx'],'D5:D37');

LineNumber=xlsread(['C:\Users\Shivansh Kumar Jha\OneDrive\Desktop\' ...
    'DSAA PROJECT\Data Values\CurrentProfile.xlsx'],'A5:A36');
CurrentMagnitude=xlsread(['C:\Users\Shivansh Kumar Jha\OneDrive\Desktop\' .
    'DSAA PROJECT\Data Values\CurrentProfile.xlsx'],'F5:F36');
CurrentAngle=xlsread(['C:\Users\Shivansh Kumar Jha\OneDrive\Desktop\' ...
    'DSAA PROJECT\Data Values\CurrentProfile.xlsx'],'G5:G36');

plot(BusNumber,VoltageMagnitude)
xlabel('\bf Bus Number')
ylabel('\bf Voltage Magnitude(in pu)')
title('Graph of Magnitude Of Voltage')
grid on
plot(BusNumber,VoltageMagnitude)
xlabel('\bf Bus Number')
ylabel('\bf Voltage Magnitude(in pu)')
title('Graph of Magnitude Of Voltage')
grid on

plot(BusNumber,VoltageAngle)
xlabel('\bf Bus Number')
ylabel('\bf Voltage Angle')
title('Graph of Angle Of Voltage')
grid on

plot(LineNumber,CurrentMagnitude)
xlabel('\bf Line Number')
ylabel('\bf Current Magnitude(in pu)')
title('Graph of Magnitude Of Current')
grid on

plot(LineNumber,CurrentAngle)
xlabel('\bf Line Number')
ylabel('\bf Current Angle')
title('Graph of Angle Of Current')
grid on
```

POWER PROFILE

```
clear all
LineNumber=xlsread(['C:\Users\Shivansh Kumar Jha\OneDrive\Desktop\' ...
    'DSAA PROJECT\Data Values\PowerProfile.xlsx'],'A5:A36');
ActivePower=xlsread(['C:\Users\Shivansh Kumar Jha\OneDrive\Desktop\' ...
    'DSAA PROJECT\Data Values\PowerProfile.xlsx'],'F5:F36')
ReactivePower=xlsread(['C:\Users\Shivansh Kumar Jha\OneDrive\Desktop\' ...
    'DSAA PROJECT\Data Values\PowerProfile.xlsx'],'G5:G36')

plot(LineNumber,ActivePower)
xlabel('\bf Line Number')
ylabel('\bf Active Power(kW)')
title('Graph of Active Power')
grid on

plot(LineNumber,ReactivePower)
xlabel('\bf Line Number')
ylabel('\bf Reactive Power(kVar)')
title('Graph of Reactive Power')
grid on
```