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Load Flow Study of Power Distribution System with Distributed Generation Penetration

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Abstract: In this Paper Distribution system load flow studies are different from those of transmission system, because of its high R/X ratio and radial nature. Several methods have been proposed earlier for doing this distribution load flow studies, but fast load flow algorithms with better results are always needed. Load flow algorithms for two feeders which are Airport Road feeder and seven sky urban feeder of PGVCL bhuj Subdivision-2 with and without inclusion of distributed generations and these are based on backward forward sweep method by using MATLAB Programming. Attention is given to number of iterations being taken for convergence, applicability for radial distribution systems for distribution systems having distributed generation where distributed generations are Photovoltaic model.

Keywords: LFS – Load Flow Study, B/F- Backward Forward Sweep Method, DG- Distributed Generator, PGVCL- Paschim Gujarat Vij company limited, Airport Road feeder, Seven sky urban feeder.

I. INTRODUCTION

One of the most important aspects of the power system is keeping the entire system secure and reliable for this the power system operation and control engineers must know all the values at every bus and branch of network. Every network bus and branch have different values. These values include the voltage profile (voltage magnitude and voltage angle), real power and reactive power, current flows, and power losses, and so on by applying load or power flows to the network. There are various methods for solving load flows, such as Gauss-Seidel, Newton-Raphson, and Fast-Decoupled, but not all methods are used for transmission systems but in in distribution systems there are different methods such as Backward forward sweep method, Current injection method, Direct approach method. The Gauss-Seidel and Newton-Raphson methods are not useful in perfect distribution networks due to Distribution system having low X/R ratio, on a distributed network, distributed generators are being placed closer to the end user. These DGs are more reliable and secure, and they also provide a continuous power supply to the customer. As DGs, some diesel engines and renewable energy sources such as solar energy, wind turbines, and so on are used. This method can also be used to solve distribution systems that contain DGs. The load flow algorithm is primarily responsible for the distribution system's efficiency. During the calculation of power flow values, the low flow solution is executed several times. To achieve an efficient load flow solution, the distribution system must be time efficient and robust. A simple and efficient technique is developed in this work by using MATLAB Programming.

II. DISTRIBUTED GENERATION

Distributed generation is an electric power source that is directly connected to the distribution network or to the metre at the customer site. The purpose of distributed generation is to provide a source of active power. The location of distributed generation is defined as the installation and operation of electric power generation units connected directly to the distribution network or connected to the network on the customer site of the meter. The definition of distributed generation does not specify the rating of the generation source because the maximum rating is determined by local distribution network conditions, such as voltage level. DG is needed due to high transmission losses, distribution losses, rural electrification, electrical power requirement, improved reliability and power quality, possibility of load management. Classification of DG as per installation capacity like micro, mini, small, medium, and large generation of solar, tidal, fuel, biomass, wind and other resources.

Classification of DG as per Installation capacity like…

- Micro distributed generation: 1 Watt to 5 kW
- Small, distributed generation: 5 kW to 5 MW
- Medium distributed generation: 5 MW to 50 MW
- Large, distributed generation: 50 MW to 300 MW

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DG Integration into Distribution Network: Steps

• Firstly, Identify the location (Node) at which a DG unit is to be placed
• Find out the DG Power (Both Active and Reactive Power)
• If they are providing both active and reactive power, then how much active and reactive power it is providing.
• Then it considered to be a negative load assuming that it does not have this constant voltage or regulated voltage capability,
• Subtract this generation from this load demand.
• If DG is supplying reactive power as well, you can subtract this reactive power from this reactive power demand as well.

III.BACKWARD-FORWARD SWEEP METHOD ALGORITHMS AND FLOW CHART WITH DG

The proposed method presents a load flow study using the backward forward sweep method, which is one of the most effective methods for radial distribution system load flow analysis. The voltage magnitudes for each bus node are determined using this method. The obvious reason for this is that this method is simple, quick, and reliable and universal KVL ` and KCL based method.

A. Forward Sweep: The forward sweep is essentially a voltage drop calculation with possible current or load flow updates. Voltages at nodes are updated in a Sweep forward from the first layer of branches to the last layer of branches. The goal of forward propagation is to compute the voltage at each node beginning with the feeder source node. The voltage at the feeder substation is set to its actual value. The effective power in each branch is held constant to the value obtained in the backward sweep during forward propagation.

B. Backward Sweep: A backward sweep is essentially a current or load flow solution with voltage updates. It begins with the branches in the last layer and progresses to the branches connected to the root node. Backward propagation computes the updated effective power flow in each branch by taking previous iteration's node voltages into account. It means that the voltage values obtained during the forward sweep are held constant during backward propagation, and that updated power flows in each branch are transmitted backward along the feeder using backward sweep. This indicates that backward propagation begins at the far end node and progresses towards the source node.
A feeder load-flow analysis can determine the following by B/F sweep method.

• Voltage magnitude and angle at all feeder nodes.
• Line flow specified in kW and kVAR, amp and degrees, or amps and
• Each line section has a power loss.
• Total feeder input, in kW and in kVAR
• Total feeder power wastage.

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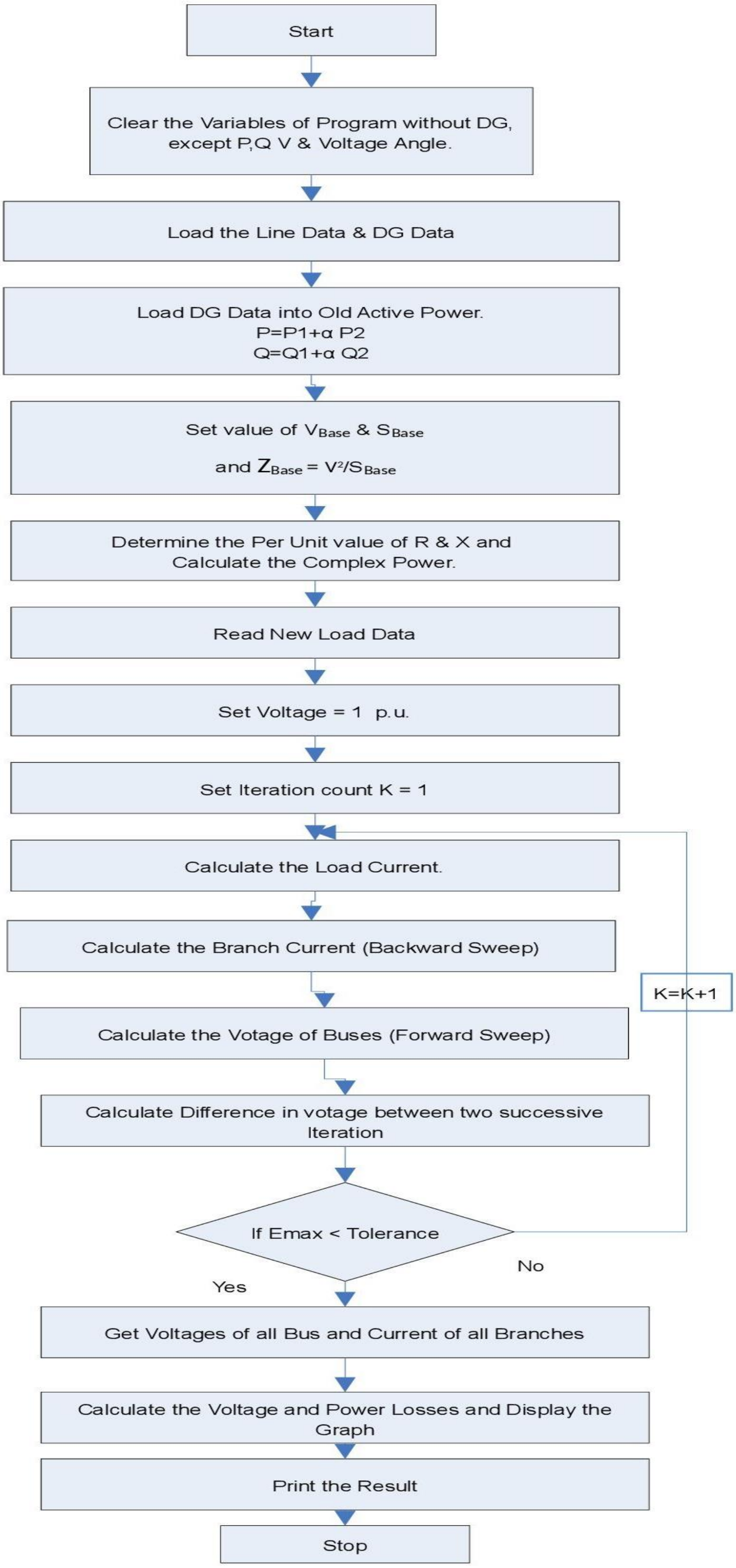

Fig.1.1 Flow chart with DG for proposed method

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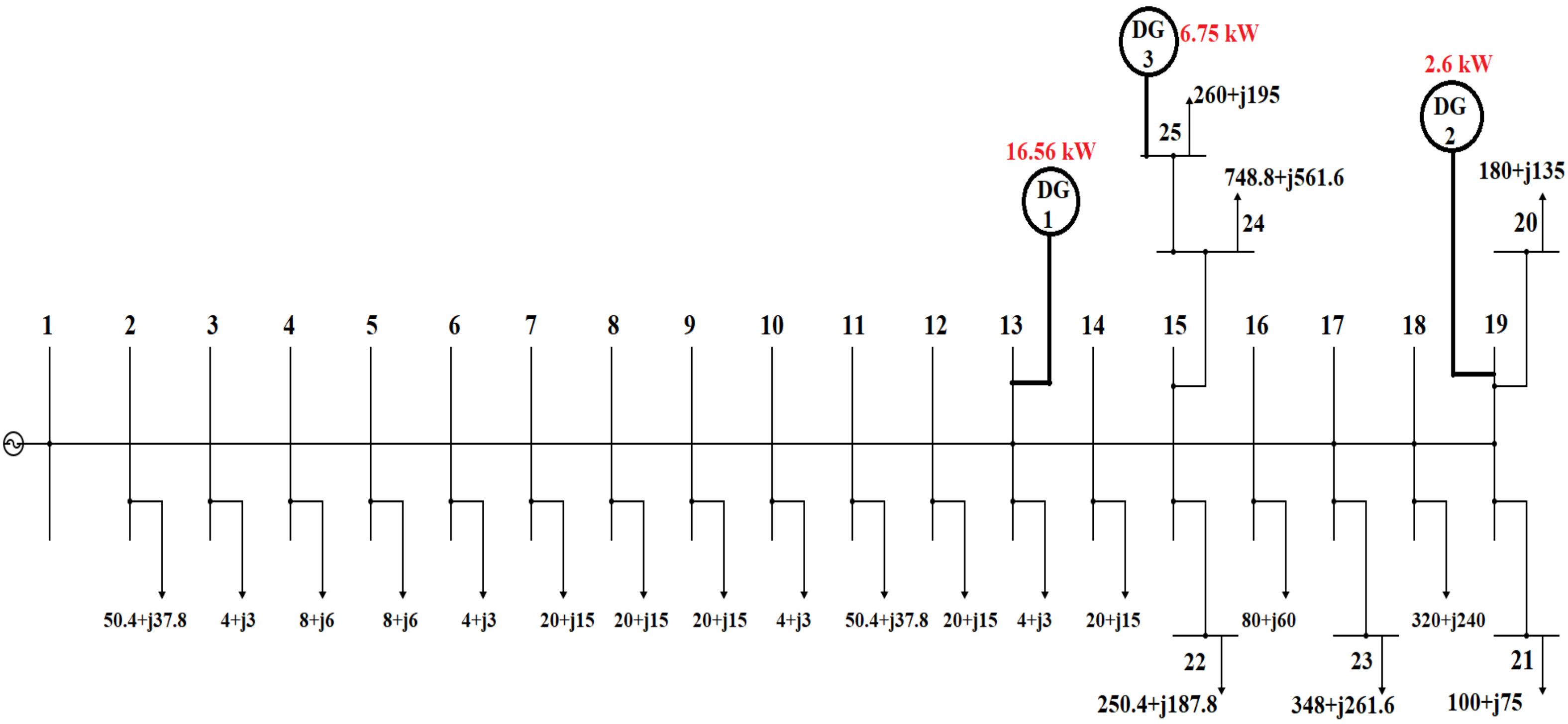
IV. MATLAB PROGRAMMING AND RESULUTS WITH DISTRIBUTED GENERATION

In this section, the load flow analysis of Airport Road feeder and seven sky urban feeder of Bhuj city subdivion-2 Distribution system is done using BFS algorithm and find out the voltage profile and power losses of the Distribution System.
Firstly, using proposed method make the load flow analysis with the help of MATLAB software. Formulate the test system & with the help of programming and will find their data and results and then comparing the results obtained from both with and without DG.

V. AIRPORT ROAD FEEDER OF BHUJ CITY

FIGURE 1.2 SCHEMATIC DIAGRAM FOR AIRPORT ROAD FEEDER



In this 25 Bus radial Distribution system show in diagram. The data of system are given, substation bus with a voltage of 11 kV and the symbols R and X denote the resistance and reactance of the feeder section between Bus 1 to bus 25, respectively. Further, here denote the real and reactive power loads, respectively, for solving the load flow, initially all the bus voltages are initialized to 11 kV node. For computing the load flow solution, a tolerance of 10^{-6} has been chosen and the algorithm converged in 46 iterations.

Airport Road feeder distribution network with entire connected load of 2520.8 kW and 1890.6 kVAr. and the SPV DGs connected at bus 13,19 and 25 rating are 16.56 kW,2.6 kW,6.75 kW. It has been seen that the voltage profile improves with connection of PV DGs.25.91 kW. If It's Calculated as a percentage relative to total load demand so percentage of DG, it comes to 1.02%. The comparative analysis in Airport Road feeder of real power losses with DG is 121.7573 kW and without DG 124.5714 is kW. This means that real power losses are 2.8141kW reduced in Airport Road feeder. It has been observed that the voltage profile of busses is improved after DG placement.

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Table 1.1 Airport Road feeder Line data

Line Number	Sending node	Receiving node	Resistance	Reactance
1	1	2	0.115605	0.052458501
2	2	3	0.139973	0.063516041
3	3	4	0.19074	0.086552582
4	4	5	0.006949	0.003153259
5	5	6	0.069279	0.031436777
6	6	7	0.01491	0.006765839
7	7	8	0.089188	0.040471046
8	8	9	0.066751	0.030289881
9	9	10	0.161479	0.073274517
10	10	11	0.09084	0.041220614
11	11	12	0.755794	0.342958441
12	12	13	0.129007	0.058539584
13	13	14	0.028237	0.012813107
14	14	15	0.018146	0.008233978
15	15	16	0.042389	0.019235159
16	16	17	0.457776	0.207726196
17	17	18	0.025436	0.011542223
18	18	19	0.196155	0.089009813
19	19	20	0.250797	0.113804739
20	20	21	0.279941	0.127029264
21	21	22	0.138595	0.062890461
22	22	23	0.346307	0.157144433
23	23	24	0.249133	0.113049535
24	24	25	3.026909	1.373527337

Table 1.2 Airport Road feeder Load data

Bus number	Active power(kw)	Reactive power(kvar)
1	0	0
2	50.4	37.8
3	4	3
4	8	6
5	8	6
6	4	3
7	20	15
8	20	15
9	20	15
10	4	3
11	50.4	37.8
12	20	15
13	4	3
14	20	15
15	0	0
16	80	60
17	0	0
18	320	240
19	0	0
20	180	135
21	100	75
22	250.4	187.8
23	348.8	261.6
24	748.8	561.6
25	260	195

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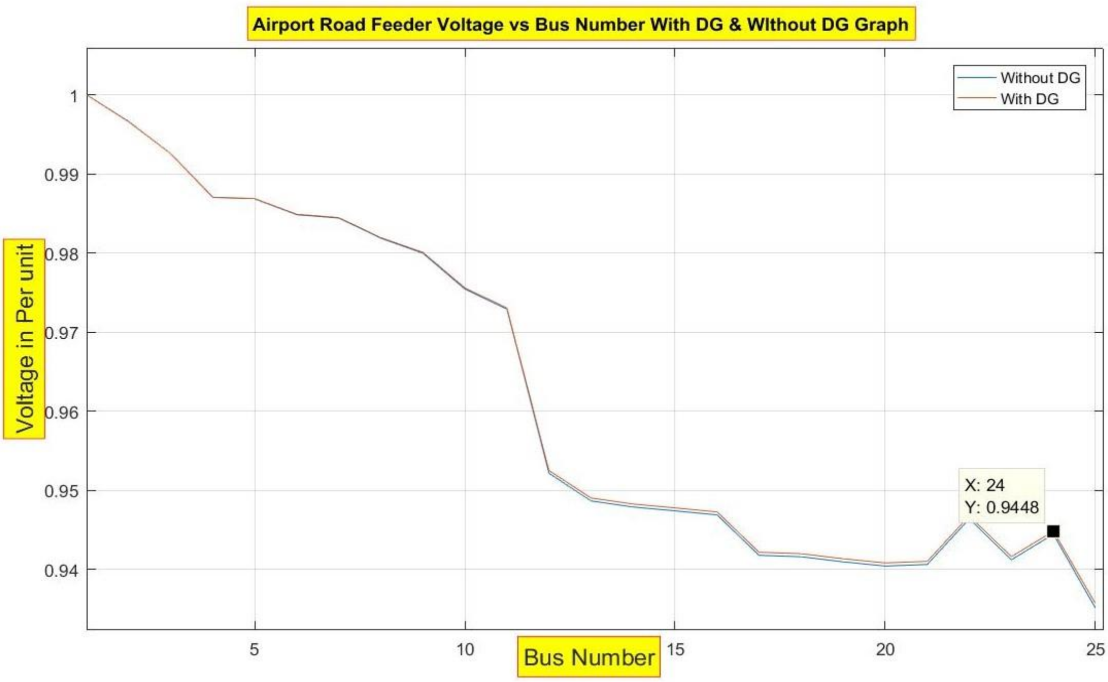
Table 1.3 DG insert Table in AIRPORT ROAD feeder

Bus Number	**DG Capacity in kW**
13	16.56 kW
19	2.6 kW
25	6.75 kW

Table 1.4 Comparison Voltage without & With DG of MATLAB Result for Airport Road Feeder

Bus Number	Voltage Without DG	Voltage With DG
1	1	1
2	0.9966	0.9966
3	0.9926	0.9926
4	0.987	0.9871
5	0.9868	0.9869
6	0.9848	0.9849
7	0.9844	0.9845
8	0.9819	0.982
9	0.98	0.9801
10	0.9755	0.9756
11	0.9729	0.9731
12	0.9522	0.9525
13	0.9487	0.949
14	0.9479	0.9483
15	0.9474	0.9478
16	0.9469	0.9473
17	0.9418	0.9422
18	0.9416	0.942
19	0.941	0.9414
20	0.9404	0.9408
21	0.9406	0.941
22	0.9464	0.9468
23	0.9412	0.9416
24	0.9445	0.9448
25	0.9351	0.9357

Figure 1.3 Airport Road Feeder with & without DG bus vs Voltage Graph



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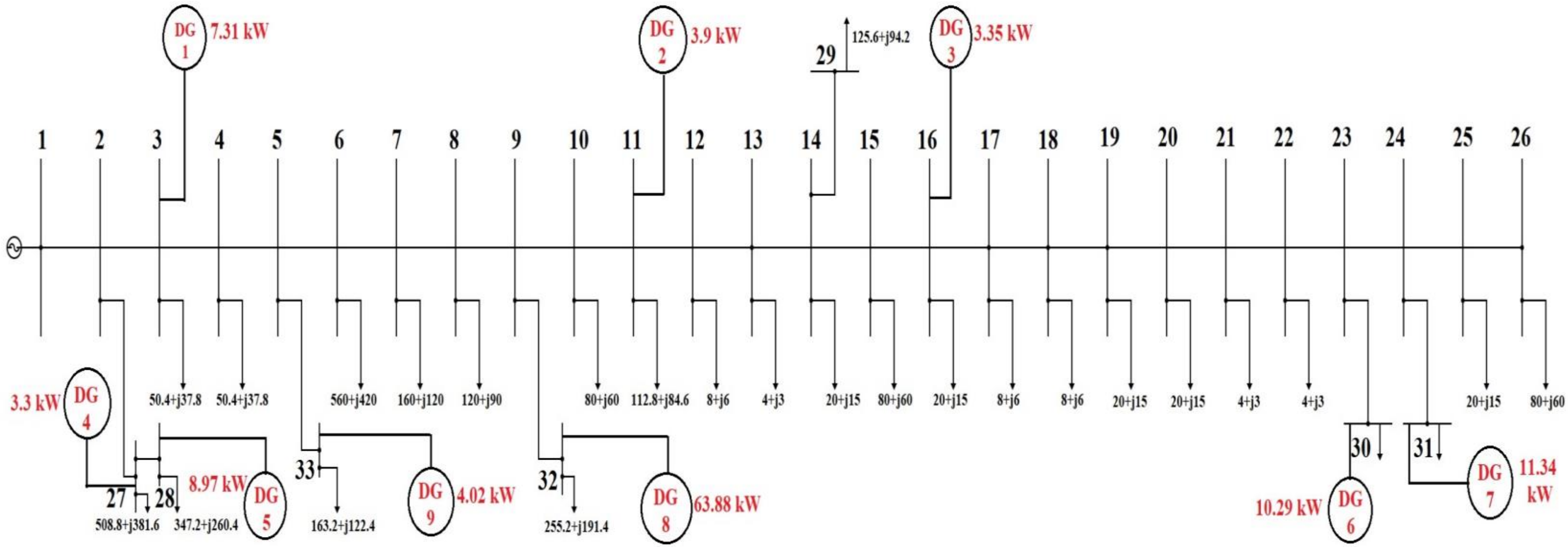
VI.SEVEN SKY URBAN FEEDER OF BHUJ CITY

Figure 1.4 Schematic diagram for Seven sky urban feeder with DG



In this Seven sky urban feeder Distribution system show in diagram. The data of system are given in Table In this system, substation bus with a voltage of 11 kV and the symbols R and X denote the resistance and reactance of the feeder section between Bus 1 to bus 33, respectively. Further, here denote the real and reactive power loads, respectively, for solving the load flow, initially all the bus voltages are initialized to 11 kV node. For computing the load flow solution, a tolerance of 10^{-6} has been chosen and the algorithm converged in 46 iterations.

The proposed method has been executed on Seven sky urban feeder distribution network with entire connected load of 3341.6 kW and 2506.2 kVAr and the SPV DGs connected at total nine buses. It has been seen that the voltage profile improves with connection of PV DGs.116.36 kW. If It's Calculated as a percentage relative to total load demand so percentage of DG, it comes to 3.48 %.

The comparative analysis in Seven sky urban feeder of real power losses with DG is 155.1274 kW and without DG is 200.8556 kW. This means that real power losses are 45.7282 kW reduced in Seven sky urban feeder. It has been observed that the voltage profile of busses is improved after DG placement.

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Table 1.5 Seven sky urban feeder Line data

Branch No.	Sending Node	Receiving Node	Resistance	Reactance
1	1	2	1.336206	0.606333
2	2	3	0.194733	0.088365
3	3	4	0.060957	0.027661
4	4	5	0.006949	0.003153
5	5	6	0.017816	0.008085
6	6	7	0.03128	0.014194
7	7	8	0.142029	0.064449
8	8	9	0.016357	0.007422
9	9	10	0.172396	0.078228
10	10	11	0.019841	0.009003
11	11	12	0.064056	0.029067
12	12	13	0.031081	0.014104
13	13	14	0.130075	0.059024
14	14	15	0.094491	0.042878
15	15	16	0.042967	0.019497
16	16	17	0.055555	0.025209
17	17	18	0.091983	0.041739
18	18	19	0.058424	0.026511
19	19	20	0.218828	0.099298
20	20	21	0.103632	0.047026
21	21	22	0.236769	0.107439
22	22	23	0.049562	0.02249
23	23	24	0.221815	0.100653
24	24	25	0.152549	0.069222
25	25	26	0.020096	0.009119
26	26	27	0.687764	0.312088
27	27	28	0.410419	0.816237
28	28	29	0.204955	0.093003
29	29	30	0.193249	0.087691
30	30	31	0.203719	0.092442
31	31	32	0.265732	0.120582
32	32	33	0.869568	0.394586

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Table 1.6 Seven sky urban feeder Load data

Bus No	P	Q
1	0	0
2	0	0
3	50.4	37.8
4	50.4	37.8
5	0	0
6	560	420
7	160	120
8	120	90
9	0	0
10	80	60
11	112.8	84.6
12	8	6
13	4	3
14	20	15
15	80	60
16	20	15
17	8	6
18	8	6
19	20	15
20	20	15
21	4	3
22	4	3
23	0	0
24	0	0
25	20	15
26	80	60
27	508.8	381.6
28	347.2	260.4
29	125.6	94.2
30	200.8	150.6
31	311.2	233.4
32	255.2	191.4
33	163.2	122.4

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Table 1.7 DG insert Table in Seven sky urban feeder

Bus Number	**DG Capacity in kW**
3	7.31
11	3.9
16	3.35
27	3.3
28	8.97
30	10.29
31	11.34
32	63.88
33	4.02

Table 1.8 Comparison Voltage without & With DG of MATLAB Result for Seven sky urban Feeder

Bus Number	Voltage Without DG	Voltage With DG
1	1	1
2	0.947	0.9519
3	0.9412	0.9467
4	0.9395	0.9451
5	0.9393	0.9449
6	0.9388	0.9445
7	0.9382	0.9439
8	0.9356	0.9417
9	0.9354	0.9414
10	0.933	0.9393
11	0.9328	0.9391
12	0.9321	0.9385
13	0.9317	0.9382
14	0.9303	0.9369
15	0.9294	0.9361
16	0.929	0.9358
17	0.9286	0.9353
18	0.9278	0.9347
19	0.9274	0.9343
20	0.9257	0.9328
21	0.9249	0.9321
22	0.9232	0.9305
23	0.9228	0.9302
24	0.9217	0.9292
25	0.9215	0.929
26	0.9215	0.929
27	0.9443	0.9494
28	0.9408	0.9461
29	0.93	0.9366
30	0.9218	0.9293
31	0.9191	0.9269
32	0.9348	0.941
33	0.9389	0.9445

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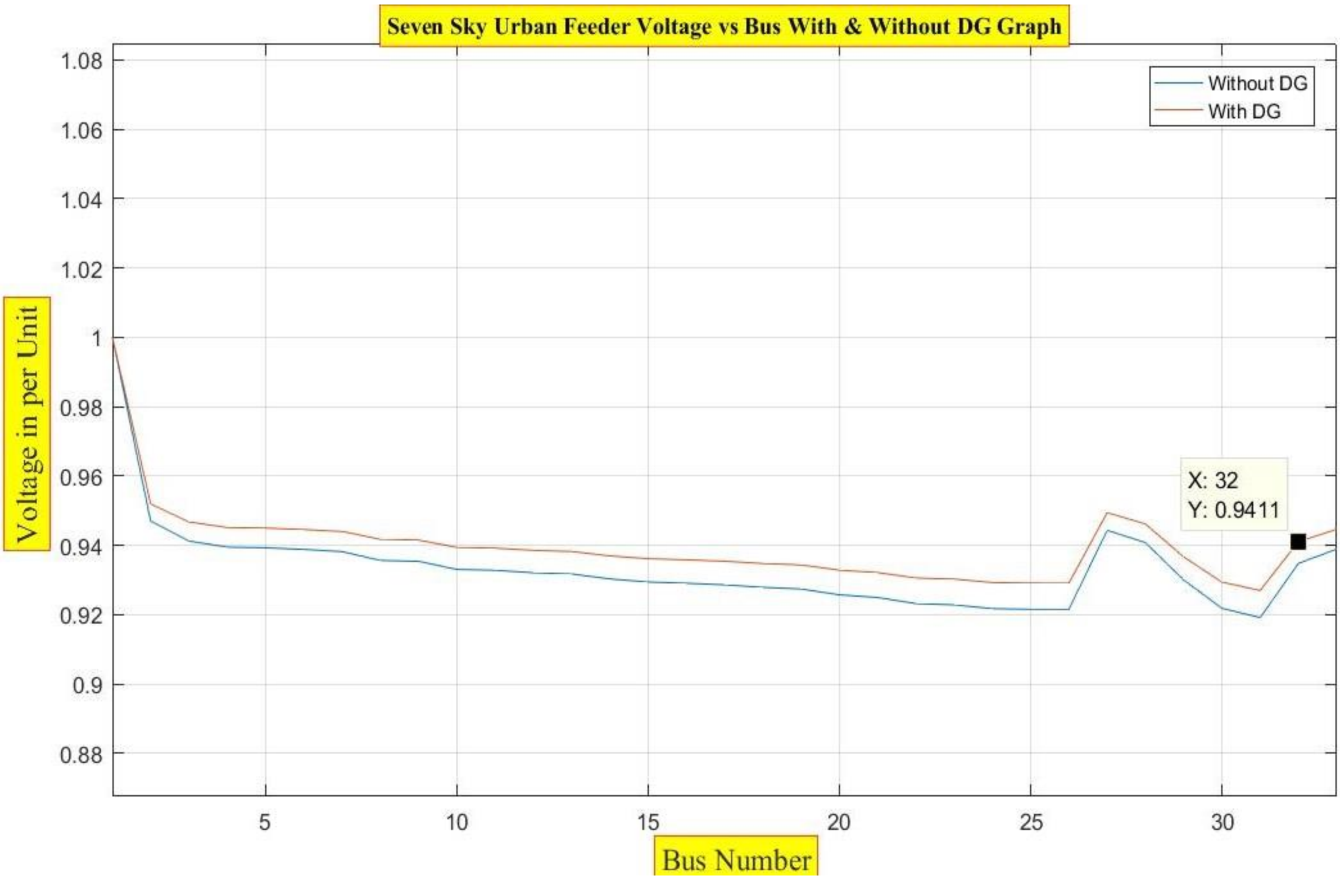
Figure 1.5 Seven sky urban Feeder with & without DG bus vs Voltage Graph



CONCLUSION

- This dissertation ends of providing an efficient load flow analysis for distribution system with and without DG. For this load flow analysis line and load data of 6 buses and 31 buses [12] has been taken for analysis. The result of this load flow analysis has been also compared with [12] and verified.
- The load flow of six buses is converged at a 11th iteration and that of 31 buses converged 51th iterations.
- Similarly, the line and load data of two feeders Airport Road feeder and seven Sky urban feeder, PGVCL Bhuj subdivision 2, has been taken for the load Flow analysis. First a load analysis of both this feeder has been done without penetration of the DG. From the result it is conclude that in airport road feeder voltage drop of 6.48 % is observed while in Seven Sky Urban feeder the voltage drop is observed 8.09%.
- Also, Airport Road feeder active and reactive both the power losses are observed which are 124.5714 kW and 137.8122 kVAr While seven sky urban feeder active and reactive both the power losses are observed which are 200.8556 kW and 220.3943 kVAr.
- Then the proposed method has been executed on IEEE-33 Buses [7] with the penetration of DG. The result of the load flow analysis also verified with [7]. From the result it is conclude that IEEE-33 Bus System voltage drop is observed 9.62 %.
- The proposed method has been also executed on Airport Road feeder Seven Sky urban feeder of distribution system PGVCL Bhuj Subdivision-2 with Penetration of DG. Total DG Penetration on Airport Road feeder is 1.02 percentage & Seven Sky urban feeder DG Penetration is 3.48 %.
- From the result it is percentage of voltage drop in the Airport Road feeder is improved from 6.43% To 6.48% Also, power losses are reduced from 124.5714 kW to 121.7573kW and voltage drop in the Seven sky urban feeder is improved from 7.3 % To 8.09%. Also, power losses are reduced from 200.8556 kW to 155.1274 kW
- So, it can be concluded that the number of percentage penetration of DG increases the voltage profile also increases.

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