Improvement of Voltage Profile through the Distributed Generation in Power System Network

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ABSTRACT

The impending deregulated environment faced by the electric utilities in the twenty first century is both a challenge and an opportunity for a variety of technologies. The need to provide acceptable power quality and reliability will create a very favorable climate for the entry of distributed resources and innovative operating practices. Of all the different parts of an electric power system, customers identify closely with the distribution subsystem due to its proximity and visibility on a daily basis. Several recent developments have encouraged the entry of power generation and energy storage at the distribution level. A distributed utility will use both distributed resources and load management to achieve its goal. In addition, several compact distributed generation technologies are fast becoming economically viable. Integration of Distributed generation into an existing utility can result in several benefits. These benefits include increase voltage profile, increased overall energy efficiency, relieved transmission and distribution congestion, voltage support, and deferred investments to upgrade existing generation, transmission, and distribution systems. Benefits are not limited to utility. Customers also benefit from Distributed generation in term of better quality of electric power at lower cost. The Distributed Generation (DG) has created a challenge and an opportunity for developing various novel technologies in power generation. The proposed work discusses the primary factors that have lead to an increasing interest in DG. DG increases system voltage profile and hence improves power quality. The proposed work finds out the optimal value of the DG capacity to be connected to the existing system. The line voltage stability index obtained by performing a conventional Newton-Raphson load flow solution calculates accurately the proximity of the operating point to the voltage collapse point and hence validates the significance of the proposed method. The optimum value of the DG obtained increases the maximum load ability of the system. The proposed method is tested on a standard IEEE-14 bus system and the results of the simulation using C++ .The method has a potential to be a tool for identifying the best location and rating a DG to be installed for improving power quality in an electrical power system.

I. INTRODUCTION

Distributed generation can be considered as "taking power to the load". Distributed generator promises to generate electricity with high efficiency and low pollution. Unlike large central power plants, Distributed generator can be installed at or near the load. Distributed generator ratings range from 5 kW up to 100 MW. Maintenance cost for Distributed generator such as fuel cells and photovoltaic's is quite low because of the absence of moving parts. Several recent developments have encouraged the entry of power generation and energy storage at the distribution level. Some of the major ones are listed below.

- With expanded choice, customers are demanding customized power supplies to suit their needs.
- Advent of several technologies with reduced environmental impacts and high conversion efficiencies.
- Advent of efficient and cost-effective power electronic interfaces to improve reliability and power quality.
- Ability to effectively control a number of components and subsystems using state-of-the-art computers to manage loads, demands, power flows, and customer requirements.

Several Distributed generation technologies are under various stages of development. They include micro turbines, photovoltaic systems (PV), wind energy conversion systems (WECS), gas turbines, gas-fired IC engines, diesel engines, and fuel cell systems. At present, wind energy has become the most competitive among all renewable energy technologies. Integration of DG into an existing utility can result in several benefits. These benefits include line loss reduction, reduced environmental impacts, peak shaving, increased overall energy efficiency, relieved transmission and distribution congestion, voltage support.

The Distributed Generation (DG) has created a challenge and an opportunity for developing various novel technologies in power generation. The work discusses the primary factors that have lead to an increasing interest in DG. DG reduces line losses, increases system voltage profile and hence improves power quality. Benefits of employing DG are analyzed using Voltage Profile Improvement Index (VPII).

II. BENEFITS OF THE DISTRIBUTED GENERATION

In order to evaluate and quantify the benefits of distributed generation suitable mathematical models must be employed along with distribution system models and power flow calculations to arrive at indices of benefits. Among the many benefits three major ones are considered: Voltage profile improvement, line loss reduction and line voltage stability.

In order to find out optimal placement of distributed generator, the system is tested on a system, 14 bus standard IEEE system have been taken as reference for experimental. A C++ program has been developed for power flow analysis and for the load flow of the system. The method has a potential to be a tool for identifying the best location and rating a DG to be installed for improving power quality in an electrical power system. Figure show the single line diagram of the 14 bus system.

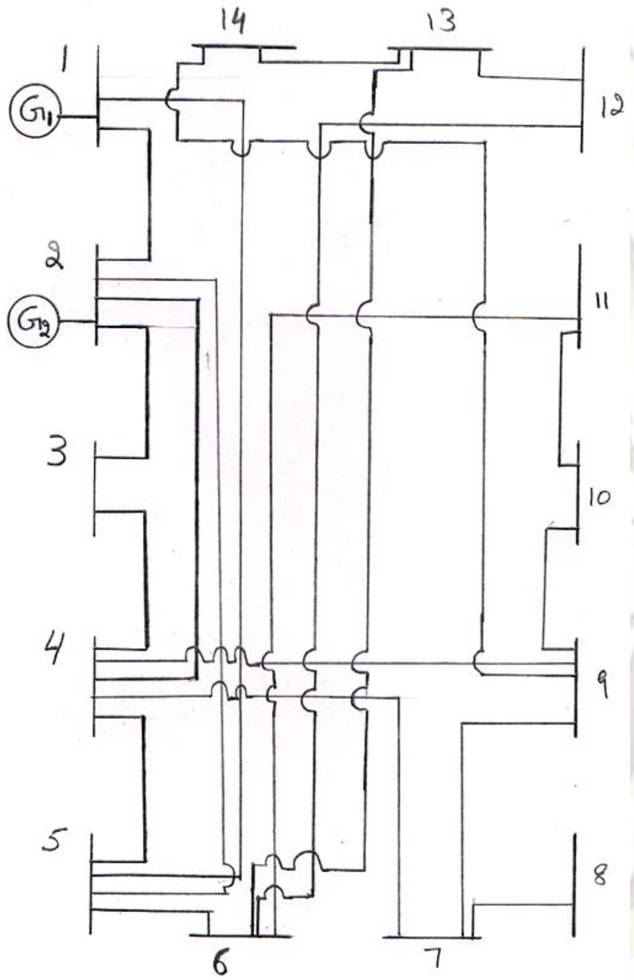


Figure Shows a Standard IEEE 14-Bus System

The line data, bus data and load flow results given in Tables and respectively. The data is on 100MVA base.

Table: Line Data

Line No.	From Bus	To Bus	Line Impedance	
			Resistance (p. u.)	Reactance (p. u.)
1	1	2	0.01938	0.05917
2	2	3	0.004699	0.19797
3	2	4	0.05811	0.17632
4	1	5	0.05403	0.22304
5	2	5	0.05695	0.17388
6	3	4	0.06701	0.17103

7	4	5	0.01335	0.04211
8	5	6	0.00000	0.25202
9	4	7	0.00000	0.20912
10	7	8	0.00000	0.17615
11	4	9	0.00000	0.55618
12	7	9	0.00000	0.11001
13	9	10	0.03181	0.08450
14	6	11	0.09498	0.19890
15	6	12	0.12291	0.25581
16	6	13	0.06615	0.13027
17	9	14	0.12711	0.27038
18	10	11	0.08205	0.19207
19	12	13	0.22092	0.19988
20	13	14	0.17093	0.34802

(Source: IEEE Data 2, pg. 143)

Table : Bus Data

Bus No.	Bus Voltage		Generation		Load	
	Magnitude (p.u.)	Phase angle (degrees)	Real power (p.u.)	Reactive power (p.u.)	Real power (p.u.)	Reactive power (p.u.)
1	1.060	0.000	2.324	-0.169	0.000	0.000
2	1.045	0.000	0.400	0.000	0.217	-.3
3	1.010	0.000	0.000	0.000	0.942	-.04
4	1.000	0.000	0.000	0.000	0.478	-.05
5	1.000	0.000	0.000	0.000	0.076	-.6
6	1.070	0.000	0.000	0.000	0.0112	-.157
7	1.000	0.000	0.000	0.000	0.000	0.0
8	1.090	0.000	0.000	0.000	0.000	0.0
9	1.000	0.000	0.000	0.000	0.295	.0006
10	1.000	0.000	0.000	0.000	0.090	-.4
11	1.000	0.000	0.000	0.000	0.035	.0001
12	1.000	0.000	0.000	0.000	0.061	-.03
13	1.000	0.000	0.000	0.000	0.135	.02
14	1.000	0.000	0.000	0.000	0.149	.01

(Source: IEEE Data 2, pg. 144)

Present work: In this thesis we have used Newton-Raphson method for the load flow. The load flow of the 14 bus system has been taken. Distributed generator has been inserted at every bus. Load flow has been taken at every bus. Voltage profile improvement index has been found out each bus. Compare the voltage profile improvement index at 2% pu distributed generator, at 5% pu Distribution generator and 10% pu distributed generator of total real load. A program in C++ was developed and different location for DG set. Voltage profile improvement index as listed above was calculated.

III. THE FOLLOWING ATTRIBUTES ARE

- Voltage profile improvement index < 1, Distribution generator has not beneficial,
- Voltage profile improvement index = 1, Distribution generator has no impact on the system voltage profile,
- Voltage profile improvement index > 1 Distribution generator has improved the voltage profile of the system.
- Distributed generator value is 2%, 5%and 10% of total real load.
- Load is Y-connected; line current is the same as phase current; $I_L = I_P$
- Load absorbs real power at some specified power factor
- DG produces real power at a lagging or leading or unity power factor
- V_P is the RMS load phase voltage. V_P is the reference phasor, The load complex power is $S_L = P_L + jQ_L$, therefore, the current absorbed by load is:

$$I_L = \frac{P_L - jQ_L}{3V_P}$$

IV. VOLTAGE PROFILE IMROVEMENT INDEX

The inclusion of DG results in improved

voltage profile at various buses. The Voltage Profile Improvement Index (VPII) quantifies the improvement in the voltage profile(VP) with the inclusion of DG. It is expressed as,

Voltage profile improvement index = Voltage profile with DG/ Voltage profile without DG

Where, DG is distributed generator

Based on this definition, the following attributes are:

VPII < 1, DG has not beneficial,

VPII = 1, DG has no impact on the system voltage profile,

VPII > 1 DG has improved the voltage profile of the system.

The general expression for VP is given as,

$$VP = \sum_{i=1}^{N} V_i L_i K_i$$

$$\sum_{i=1}^{N} K_i = 1$$

Where, V_i, is the voltage magnitude at bus i in per-unit, L_i is the load represented as complex bus power at bus i in per-unit, K_i is the weighting factor for bus i, and N is the total number of buses in the distribution system. The weighting factors are chosen based on the importance and criticality of different loads. As defined, the expression for VP provides an opportunity to quantify and aggregate the importance, amounts, and the voltage levels at which loads are being supplied at the various load busses in the system. The weighting factors are chosen based on the importance and criticality of the different loads. No overarching rules can be formulated at the present time. Starting with a set of equal weighting factors, modifications can be made and, based on an analysis of the results, the set that will lead to the most acceptable voltage profile on a system-wide basis can be selected. It should be noted that if all the load busses are equally weighted the value of K_i is given as:

$$K_1 = K_2 = K_3 = \cdots \ldots \ldots \ldots = K_N = \frac{1}{N}$$

In this case all the load buses are given equal importance. In reality, DG can be installed almost anywhere in the system. Therefore, VPII can be used to select the best location for DG.

In general, the highest value of VPII implies the best location for installing DG in terms of improving voltage profile. The voltage profile recognizes the influences of the amount and importance of load at each bus. It allows the possibility of a low-load bus with important load to have a strong impact. In general, weighting factors are assigned based on the importance/criticality of load at each bus.

V. RESULTS

TABLE: VOLTAGE PROFILE IMPROVEMENT INDEX WITH INSERT 2% DG OF TOTAL LOAD

(Values in pu)

S. NO	CASE NO	BUS NO	VOLTAGE PROFILE IMPROVEMENT INDEX WITH INSERT 2% DG OF TOTAL LOAD
1	1	2	1.000276
2	2	3	1.00044
3	3	4	1.000729
4	4	5	1.00088
5	5	6	1.00111
6	6	7	1.0001867
7	7	8	1.0015172
8	8	9	1.0017301
9	9	10	1.00195
10	10	11	1.0021722
11	11	12	1.00239615
12	12	13	1.0025936
13	13	14	1.00278059

TABLE:VOLTAGE PROFILE IMPROVEMENT INDEX WITH INSERT 5% DG OF TOTAL LOAD

(Values in pu)

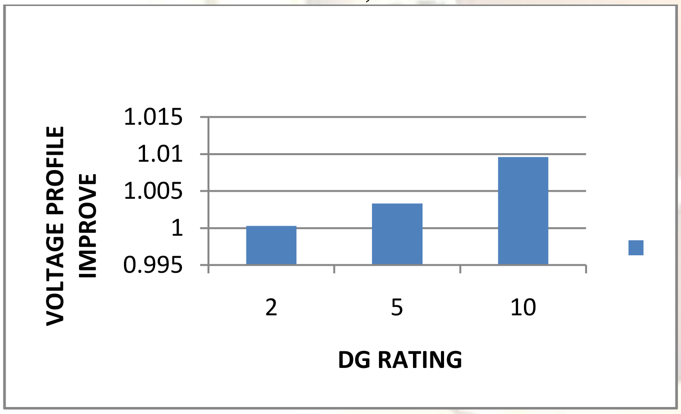
S. NO	CASE NO	BUS NO	VOLTAGE PROFILE IMPROVEMENT INDEX WITH INSERT 5% DG OF TOTAL LOAD
1	1	2	1.0033
2	2	3	1.0045
3	3	4	1.00438
4	4	5	1.00471
5	5	6	1.00513
6	6	7	1.000558
7	7	8	1.00599
8	8	9	1.006405
9	9	10	1.00645
10	10	11	1.00764
11	11	12	1.00765
12	12	13	1.0080132
13	13	14	1.008341

TABLE: VOLTAGE PROFILE IMPROVEMENT INDEX WITH INSERT 10% DG OF TOTAL LOAD
(Values in pu)

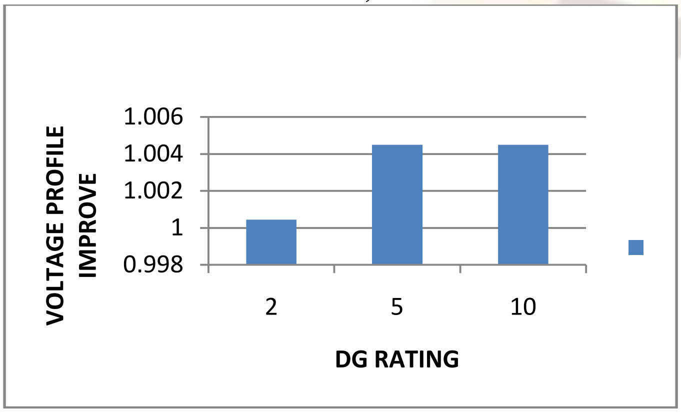
S. NO.	CASE NO	BUS NO	VOLTAGE PROFILE IMPROVEMENT INDEX WITH INSERT 10% DG OF TOTAL LOAD
1	1	2	1.00957
2	2	3	1.010562
3	3	4	1.0126
4	4	5	1.001172
5	5	6	1.012211
6	6	7	1.001279
7	7	8	1.0142
8	8	9	1.0139
9	9	10	1.0143
10	10	11	1.0149
11	11	12	1.0132
12	12	13	1.0159
13	13	14	1.01874

VI. COMPARISON OF THE DIFFERENT VOLTAGE PROFILE IMPROVEMENT INDEX

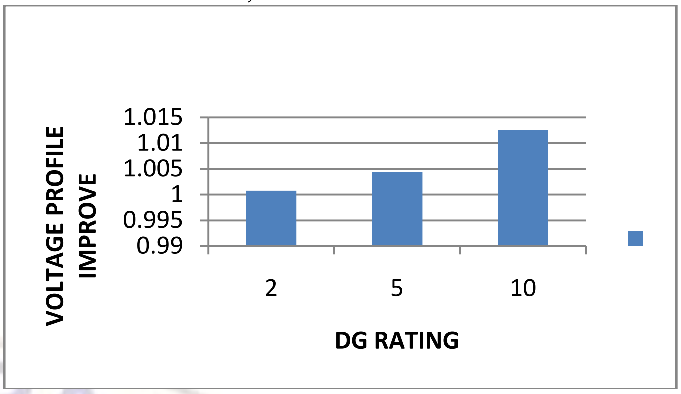
DG inserts at bus no -2, Case no-1



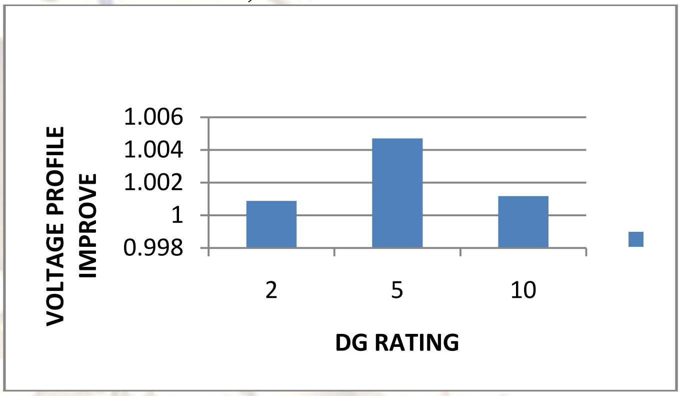
DG inserts at bus no -3, Case no-2



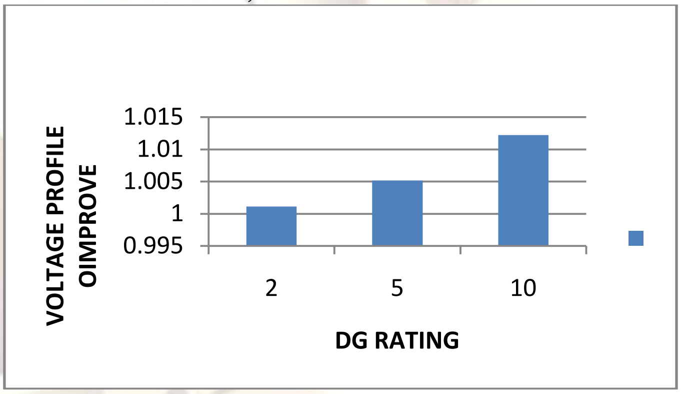
DG inserts at bus no -4, Case no-3



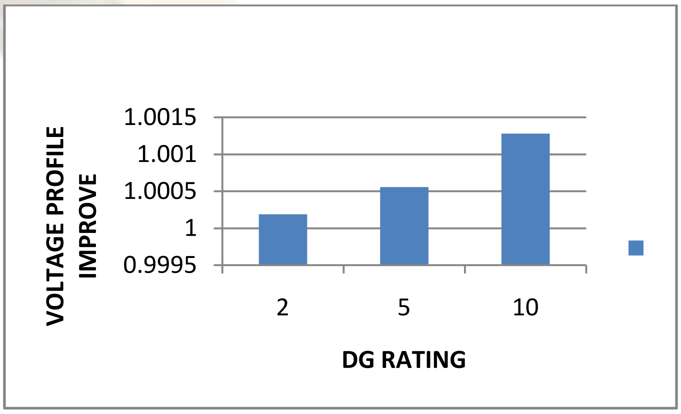
DG inserts at bus no -5, Case no-4



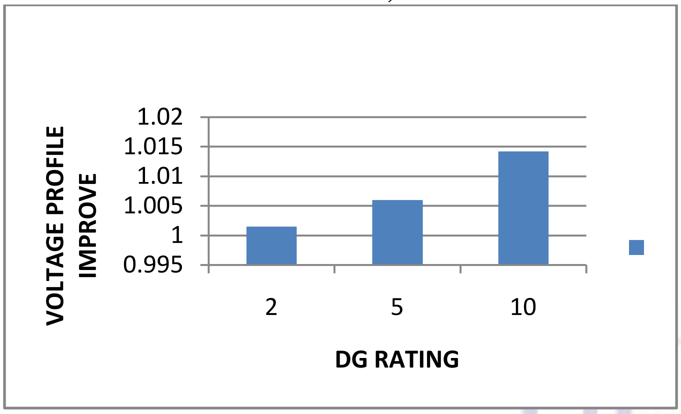
DG inserts at bus no -6, Case no-5



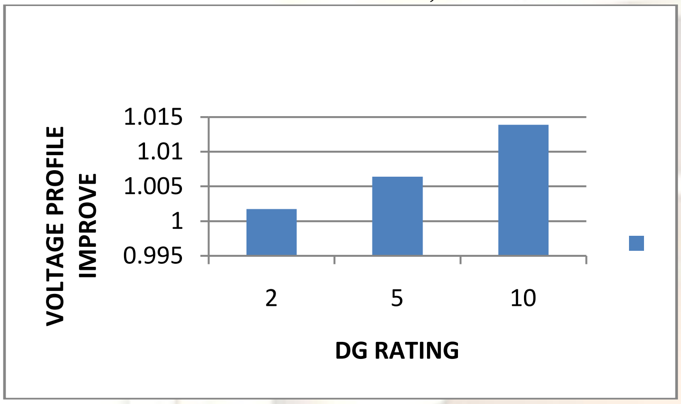
DG inserts at bus no -7, Case no-6



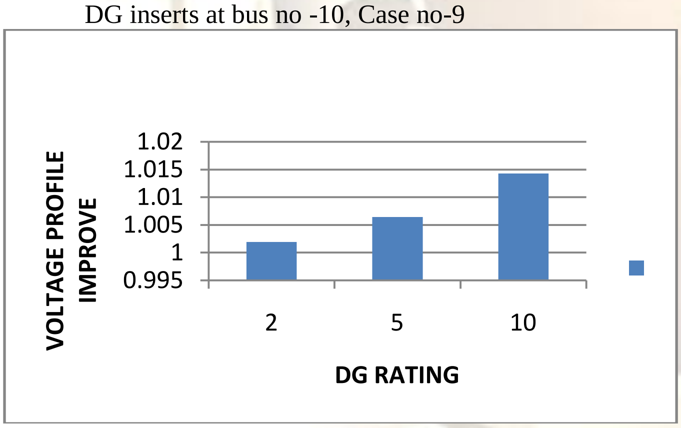
DG inserts at bus no -8, Case no-7



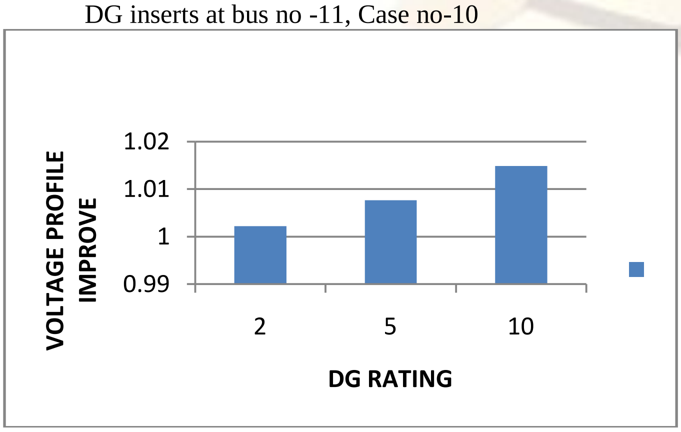
DG inserts at bus no -9, Case no-8



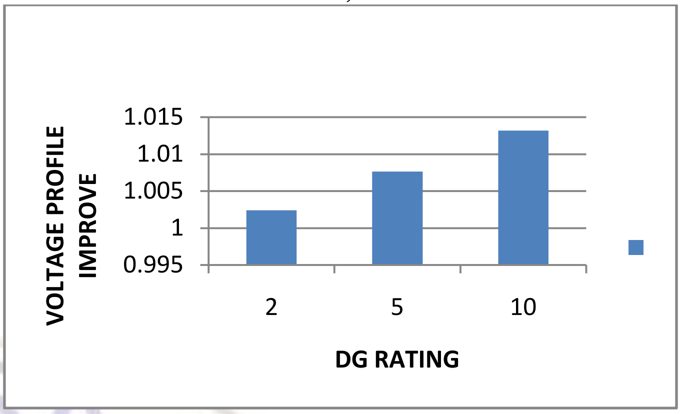
DG inserts at bus no -10, Case no-9



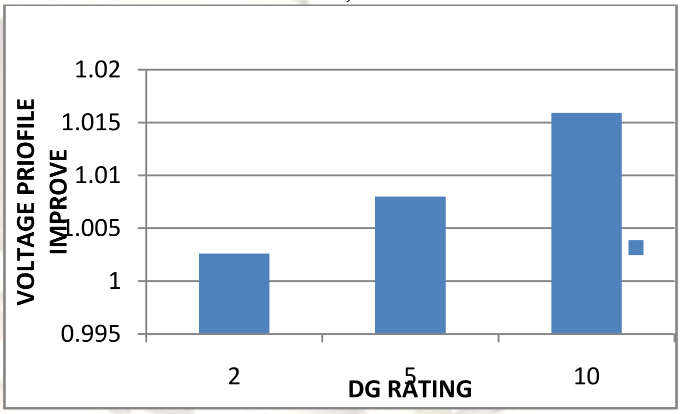
DG inserts at bus no -11, Case no-10



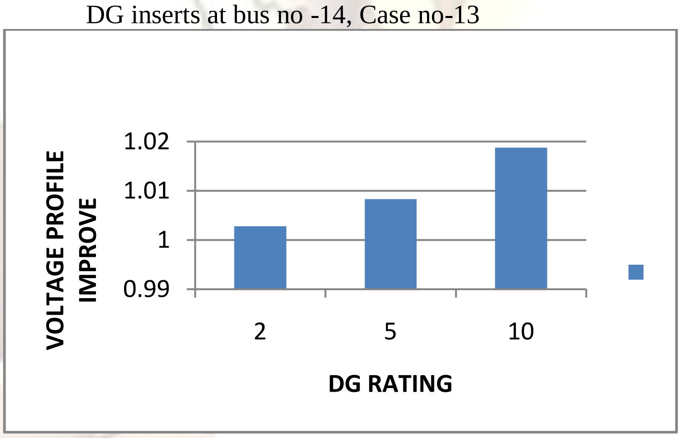
DG inserts at bus no -12, Case no-11



DG inserts at bus no -13, Case no-12



DG inserts at bus no -14, Case no-13



VII. CONCLUSION

After calculating all the results mentioned above, we concluded that voltage profile improvement index value is maximum at bus no. 14, case no.13 with 10% DG. Voltage profile improvement index is maximum when we insert the 10% DG of total real load. Voltage profile is improve with DG but at some buses it is improve very low or negligible like bus no. 7 case no.6 with 2% DG of the total real load. Clear from the result voltage profile improved at those buses maximum which has higher load as compare to other buses. At bus no.14, case no.13 with 10% DG of total real load, the voltage profile improved maximum. At bus no.7, case no.6 the voltage profile improvement index value is minimum or we can say negligible with 2% DG. Although, with 5% and 10% DG of total real load, the value of voltage profile improvement index is improved at bus no.7. But as compare to the other buses the value of voltage profile improvement index is vary low. when DG insert at lightly loaded bus or which bus has no load it is not beneficial. The DG is most beneficial at those buses which has higher load

So the insertion of DG is not the guarantee for improvement of voltage profile, its depend upon the location and other factors like its value, power factor etc.

VIII. FUTURE SCOPE

The objective here was improves voltage at the buses by inserting the DG. Line loss will be reduce using this technique and also voltage stability and power quality is improved.

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