OPTIMUM ALLOCATION OF DISTRIBUTED GENERATION BY LOAD FLOW ANALYSIS METHOD: A CASE STUDY

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Abstract

DG is nothing but a small scale generation element connected directly to the distribution network or near customer load center. DG affects the flow of power and voltage conditions at customers and utility equipment. These impacts may manifest themselves either positively or negatively depending on the distribution system operating characteristics and the DG characteristics. DG has a limited size of 10MW or less especially when DG is used in a distribution network. DG is installed at the place where it becomes unfeasible to build a central generation plant. DG is installed to improve the voltage profile as well as minimize losses. DG allocation is a crucial factor. Optimum DG allocation provides a variety of benefits. But inappropriate DG allocation can cause low or over voltage in the network. In this paper a case study is carried out for the Dharwad region, Karnataka. Load flow based method and ETAP software is used to determine the optimum location & optimum size of DG for voltage profile improvement & loss reduction.

Keywords: *Distributed Generation, Load flow Analysis, ETAP, optimum location, voltage profile improvement.*

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1. INTRODUCTION

Distributed generation is related to the use of small generation units installed in strategic points of the electric power system and mainly, close to load centers. DG can be used in an isolated way, supplying the consumer's local demand or in an integrated way, supplying energy to the remaining of the electric system. In distribution systems, DG can provide benefits for the consumers as well as for the utilities, especially in sites where the central generation is impracticable or where there are deficiencies in the transmission system. A distributed power element can be connected directly to a utility's transmission or distribution system or to consumer's terminal. Distributed generation is not centrally planned, today not centrally dispatched; it is usually connected to the distribution network & its size may be smaller than 50 or 100MW [1].

DG must be reliable, transmittable of the proper size and strategically placed to give the following system benefits: grid reinforcement, voltage support and improved power quality, loss reductions, transmission and distribution capacity release, improved utility system reliability, congestion control, Reduction in fuel and operating costs, Enhanced productivity, reduce reserve requirement, increase system security.

The optimal placement and sizing of generation units on the distribution network has been continuously studied in order to achieve different aims. The objective can be the minimization of the active losses of the feeder [2], or the minimization of the total network supply costs, which includes generators operation and losses compensation [3], [4],or even the best utilization of the available generation capacity [5]. As a contribution to the methodology for DG allocation, in this paper it is presented an algorithm for the allocation of generators in distribution networks, in order to voltage profile improvement and loss reduction in distribution network.

This paper represents a novel approach to analyze the power system network by using ETAP with the help of one line diagram. This diagram is implemented in ETAP to perform load flow study. The system is analyzed under steady state by using load flow analyses method; the data which is taken for the case is peak load data.

Section 2 is the complete single line diagram of the system under consideration; this diagram is implemented based upon practical data in ETAP for simulation purpose in Section 3 describes about load flow methodology. Section 4 and 5 consists of ETAP simulation techniques and algorithm for the case study and contains analysis which include load flow. Section 6 deals with Conclusion of this research work.

2 SINGLE LINE DIAGRAM OF CASE UNDER STUDY

Fig. 1 shows the single line diagram of the complete power system of the Dharwad, Karnataka region which is under study. It is clear from the Fig. 1 that there are two incoming lines of 110 kV supplying power to seven substations and these substations are connected with 11 kV power distribution network (11 kV feeders).

The load connected with the system is industrial load, offices load, plazas, shops and domestic load. The load can also be classified as lights, fans, air conditioners, room coolers, water coolers, printers, computers, induction motors, irrigation pumps and the other industrial equipment etc. Comprehensive load modelling is performed in ETAP based upon original system data.

Monitoring Points are also marked on the same single line diagram. The buses are named according to the substation name. Different power transformers with ratings are shown in the single line diagram to step down the voltage level. Single line diagram of the different composite network is also shown

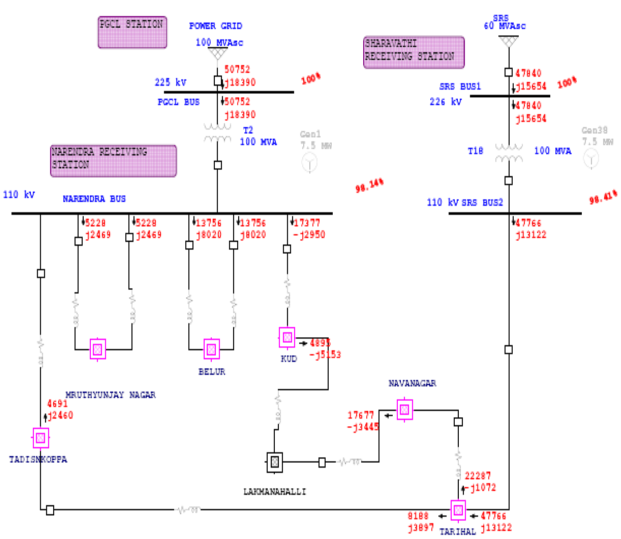

Fig -1: Single line diagram of Dharwad Area

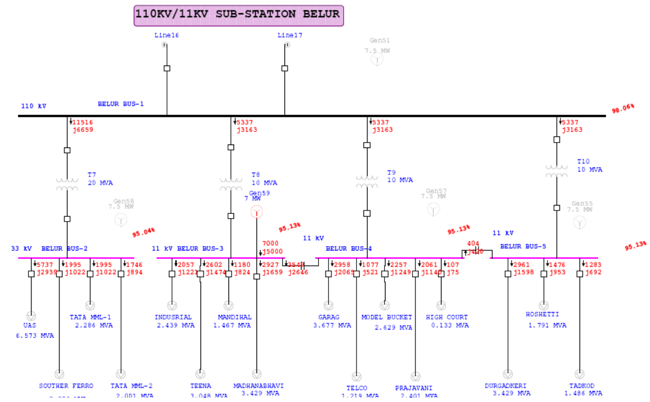

Fig -2: Single line diagram of Belur Substation

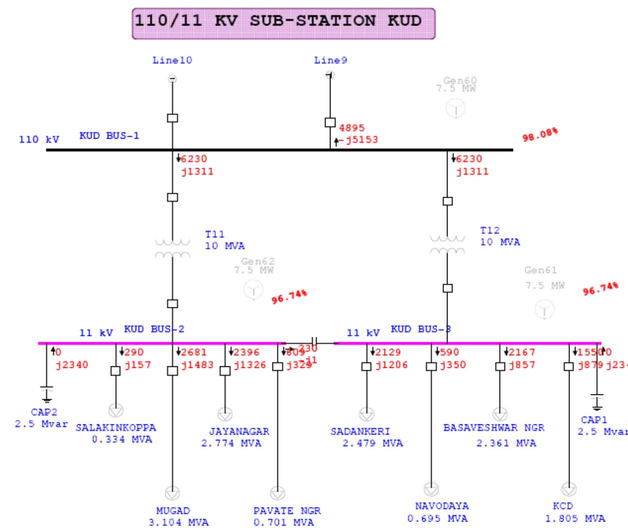

Fig -3: Single line diagram of KUD Substation

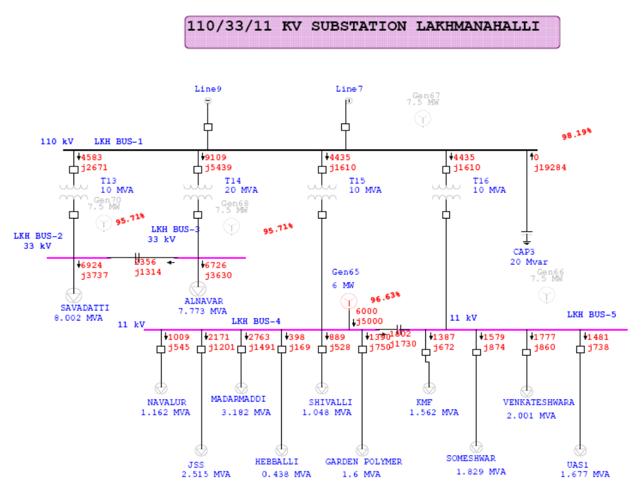

Fig -4: Single line diagram of lakmanahalli Substation

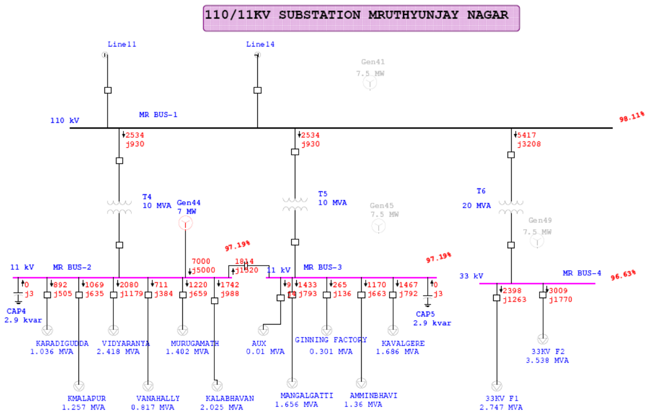

Fig -5: Single line diagram of Mrutyunjaya Substation

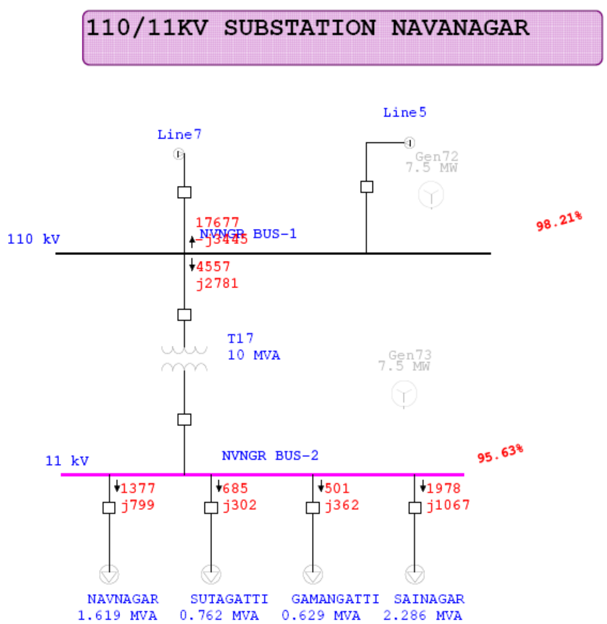

Fig -6: Single line diagram of Navnagar Substation

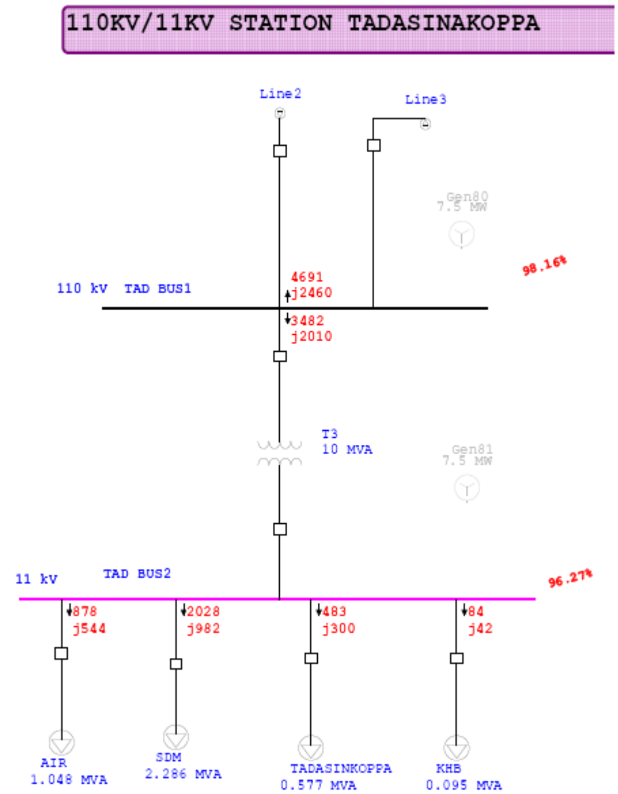

Fig -7: Single line diagram of Tadasinkoppa Substation

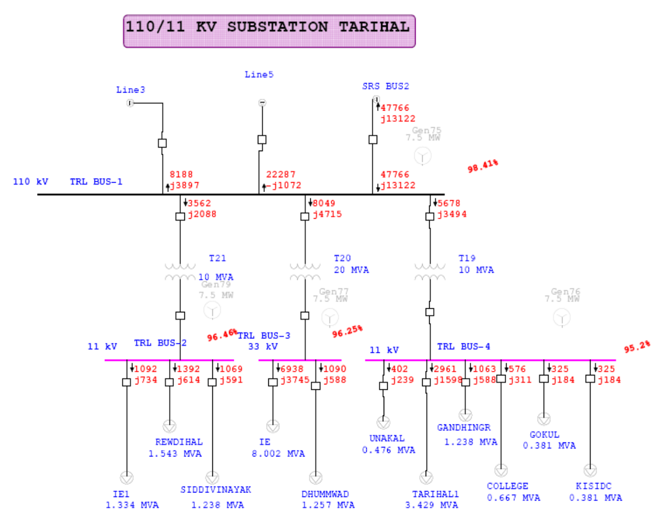

Fig -8: Single line diagram of Tarihal Substation

3. POWER FLOW ANALYSIS

Power flow analysis is one of the most common computational procedures used in power system analysis. Power flow calculation presents state of the system for a given load and generation. These studies help to analyze the steady state performance of the power system under various operating conditions. They are used to determine the circuit loading, voltages at the various buses, reactive power flow, system losses, and branch losses. The studies also helps to identify critical conditions such as over voltages, under voltages, operation near rated value etc. and desired transformer tap settings. Power flow studies and analysis of the continuous process plant with CPP was performed to ensure the security of the power system with respect to available generation capacity and voltage profiles at various buses for various operating conditions.

4. SIMULATION TECHNIQUES

The paper presents a method using load flow analysis to allocate a DG at optimum place to improve the system voltage profile also another method to select the size of Discrete Generation to maintain the a minimum loss and voltage profile

4.1 Proposed Methodology

To find the proper DG allocation in a distribution system for voltage profile improvement is the main aim of this procedure. The method is based on load flow. The sensitive buses to voltage (the buses that have a low voltage scale) are considered and ranked in the first step, the aim of this step is to install the DG unit for voltage control and the DG is placed in all buses & the voltage profile of the entire system in each installation is considered in the second step. After DG installation in each bus, the voltage profiles of all states are ranked from the best state to worst. Finally, two lists are considered to choose the best place to install the DG distribution system to provide a good voltage profile.

4.2 Computational Procedure

- Run the base case load flow
- The graph of voltage v/s bus ID is plotted
- From the graph (voltage v/s Bus ID), the priority list is formed: the sensitive buses (that should have a voltage control) in highest rank.
- DG is placed in each bus
- Run the load flow of the system after DG installation in each bus.
- Then the graphs of voltage profile of the system after placement of DG in each bus is drawn.
- Then another priority list is formed in this format: after comparing the graphs, it is required to rank them from the best profile to the worst one.
- The proper place of DG is chosen by comparing the priority list of Simulation Results i.e. the Bus ID's with the highest ranking : The load flow is done on the distribution system and the voltages are shown in table 1.

Table -1: The voltage of the buses after load flow Before DG installation

Bus ID	Voltage (P.U)	Bus ID	Voltage (P.U)
BELUR BUS-1	0.968845455	MR BUS-3	0.934363636
BELUR BUS-2	0.93830303	MR BUS-4	0.954393939
BELUR BUS-3	0.921181818	NAREND RA BUS	0.969881818
BELUR BUS-4	0.921181818	NVNGR BUS-1	0.970172727
BELUR BUS-5	0.921181818	NVNGR BUS-2	0.944181818
KUD BUS-1	0.968581818	PGCL BUS	1
KUD BUS-2	0.954636364	SRS BUS1	1
KUD BUS-3	0.954636364	SRS BUS2	0.9746
LKH BUS-1	0.969190909	TAD BUS1	0.970318182
LKH BUS-2	0.944090909	TAD BUS2	0.951272727
LKH BUS-3	0.944090909	TRL BUS-1	0.9746
LKH BUS-4	0.927454545	TRL BUS-2	0.954909091
LKH BUS-5	0.927454545	TRL BUS-3	0.952848485
MR BUS-1	0.969372727	TRL BUS-4	0.942272727
MR BUS-2	0.934363636		

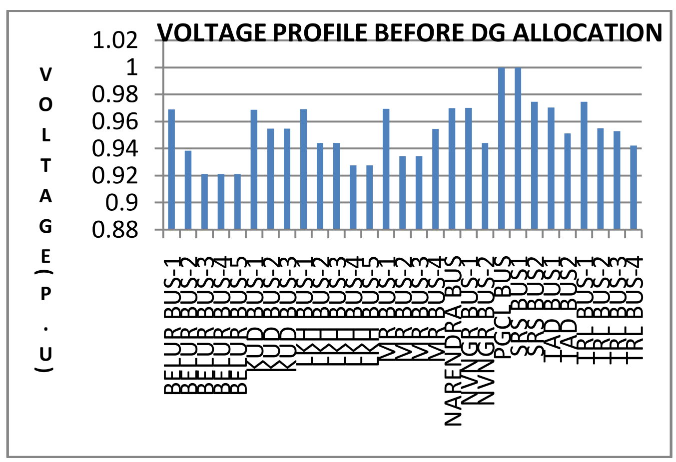

Fig -9: The voltage profile of the system before DG allocation

Now according to the algorithm, the buses should be ranked from the minimum value of the voltage to the maximum one.

Table -2: The buses are ranked from minimum value to maximum value (before DG installation)

Bus ID	Voltage P.U	Rank
BELUR BUS-3,BELUR BUS-4, BELUR BUS-5,LKH BUS-4,LKH BUS-5	0.92-0.93	1
MR BUS-2,MR BUS-3,BELUR BUS-2	0.93-0.94	2
TRL BUS-4,LKH BUS-2,LKH BUS-3, NVNGR BUS-2	0.94-0.95	3
TAD BUS2,TRL BUS-3,MR BUS-4, KUD BUS-2,KUD BUS-3,TRL BUS-2	0.95-0.96	4
KUD BUS-1,BELUR BUS-1,LKH BUS-1,MR BUS-1,NARENDRA BUS	0.96-0.97	5
NVNGR BUS-1,TAD BUS1,SRS BUS2,TRL BUS-1	0.97-0.98	6
----------	0.98-0.99	7
PGCL BUS,SRS BUS1	0.99-1.0	8

The voltage profile of each state is found after DG installation on each bus. The voltage profiles are ranked from the best profile to worst one. Table 4 shows the ranking of voltage profile of buses after DG installation.

Table -3: The voltage of the buses after load flow after dg allocation at all buses.

Bus ID	Voltage (P.U)	Bus ID	Voltage (P.U)
BELUR BUS-1	1	MR BUS-3	1
BELUR BUS-2	0.994333	MR BUS-4	1
BELUR BUS-3	1	NARENDRA BUS	1.0001
BELUR BUS-4	1	NVNGR BUS-1	1.004
BELUR BUS-5	1	NVNGR BUS-2	1
KUD BUS-1	1.002591	PGCL BUS	1
KUD BUS-2	1	SRS BUS1	1
KUD BUS-3	1	SRS BUS2	1.000745
LKH BUS-1	1.005091	TAD BUS1	1.0002
LKH BUS-2	1	TAD BUS2	1
LKH BUS-3	1	TRL BUS-1	1.000745
LKH BUS-4	1	TRL BUS-2	1
LKH BUS-5	1	TRL BUS-3	1
MR BUS-1	1.000164	TRL BUS-4	1
MR BUS-2	1		

Table -4: The buses are ranked from best voltage profile to worst voltage profile after DG installation.

Bus ID	Voltage(P.U)	Rank
LKH BUS-1,NVNGR BUS-1,KUD BUS-1,SRS BUS2,TRL BUS-1,TAD BUS1,MR BUS-1,NARENDRA BUS	1.0002-1.0051	1
BELUR BUS-1,BELUR BUS-3,BELUR BUS-4,BELUR BUS-5,KUD BUS-2,KUD BUS-3,LKH BUS-2,LKH BUS-3,LKH BUS-4,LKH BUS-5,MR BUS-2,MR BUS-3,MR BUS-4,NVNGR BUS-2,PGCL BUS,SRS BUS1,TAD BUS2,TRL BUS-2,TRL BUS-3,TRL BUS-4.	0.9951-1.00000	2
BELUR BUS-2	0.9902-0.9951	3

Comparing table 2 & 4, it is necessary to rank the best buses for DG installation.

Table 5 shows the best locations for 7.5 MW DG installation to improve the voltage profile and voltage stability. The important point that can be already considered from the table V is that the optimum DG locations are the bus ID BELUR BUS-3, LKH BUS-4 and MR BUS-2. The other ranking in the table are not very important because it is not necessary to locate the best place. The voltage profiles of the distribution system in the presence of DG in buses BELUR BUS-3, LKH BUS-4 and MR BUS-2 are shown below. It shows the voltage profile improvement.

Table -5: Optimum bus ID's for dg allocation

BUS ID	RANK
BELUR BUS-3,LKH BUS-4	1
MR BUS-2	2
BELUR BUS-2	3
TRL BUS-4,LKH BUS-2,NVNGR BUS-2	4
TAD BUS2,TRL BUS-3,MR BUS-4,KUD BUS-2, KUD BUS-3,TRL BUS-2	5
KUD BUS-1,LKH BUS-1,MR BUS-1, NARENDRA BUS	6
BELUR BUS-1	7
NVNGR BUS-1,TAD BUS1,SRS BUS2,TRL BUS-1	8
PGCL BUS,SRS BUS1	9

Table -6: voltage profile display after 7.5MW DG installation at 3 buses (MR BUS-2, BELUR BUS-3, and LKH BUS-4)

Bus ID	Voltage (P.U)	Bus ID	Voltage (P.U)
BELUR BUS-1	0.9805	MR BUS-3	0.971545455
BELUR BUS-2	0.950212121	MR BUS-4	0.966151515
BELUR BUS-3	0.951	NARENDRA BUS	0.981290909
BELUR BUS-4	0.951	NVNGR BUS-1	0.982063636
BELUR BUS-5	0.951	NVNGR BUS-2	0.956272727
KUD BUS-1	0.980681818	PGCL BUS	1
KUD BUS-2	0.967363636	SRS BUS1	1
KUD BUS-3	0.967363636	SRS BUS2	0.984036364
LKH BUS-1	0.981890909	TAD BUS1	0.9815
LKH BUS-2	0.957030303	TAD BUS2	0.962636364
LKH BUS-3	0.957030303	TRL BUS-1	0.984036364
LKH BUS-4	0.966363636	TRL BUS-2	0.964545455
LKH BUS-5	0.966363636	TRL BUS-3	0.962424242
MR BUS-1	0.981009091	TRL BUS-4	0.951909091
MR BUS-2	0.971545455		

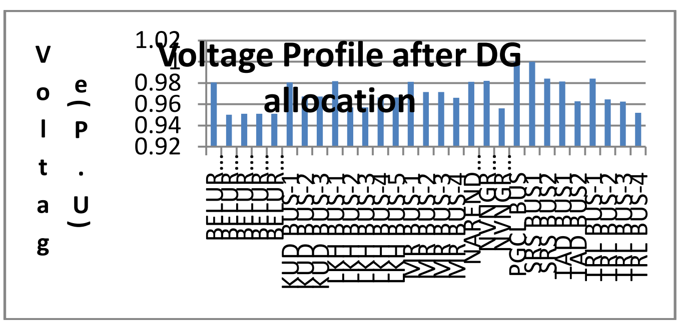

Fig -10: The voltage profile of the system after DG allocation at 3 buses

5. OPTIMUM DG SIZING

The size of DG depends upon the type of the load, power quality and secondary distribution system, for these reasons the size of DG which is considered is less than 10MW. Distributed generator larger than this is typically interconnected at transmission voltage where the system is designed to accommodate many generators.

5.1 Proposed Methodology

To find the optimum size of a DG unit in order to decrease the power loss as well as to maintain a good voltage profile of the distribution system is the aim of this procedure. To determine the optimum size it is necessary to install different sizes of DGs at optimum place (the place where total system loss is minimum)

5.2 Computational Procedure

After determining optimum DG location for voltage profile improvement, the following steps are followed for finding optimum DG size.

- In this procedure different size of DG is placed at the optimum location (i.e. at MR BUS-2, BELUR BUS-3, and LKH BUS-4 of the power system).
- It is also necessary to study the voltage profile& total loss of the system after installing DG of different size.
- The DG which provides a good voltage range with a minimum total power loss, acceptable as an optimum size.

Table -7: Comparison of voltage & total loss for different dg size at 3 buses (MR BUS-2, BELUR BUS-3, and LKH BUS-4)

DG size	Total losses		Voltage within limits
MW	MW	MVAR	
1	0.82	12.149	No
2	0.776	11.381	No
3	0.734	10.652	No
4	0.703	10.074	No
5	0.659	9.307	No
6	0.624	8.691	Yes
7	0.592	8.113	Yes
8	0.562	7.571	Yes
9	0.535	7.066	Yes

The marginal under voltage range is 0.95-0.98 P.U, bus voltage below this range is known as critical under voltage. The power system under study has a total loss of 0.958 MW & a voltage range of 0.923-1.0 P.U without DG. Bus voltage of 0.923 P.U is below the lower limit of marginal under voltage, called critical under voltage. So the voltage profile (0.923-1.0 P.U) of power system under study without DG provides a worse voltage profile & the total loss of the system is high. It is necessary to install DG of optimum size at optimum location to improve the voltage profile as well as to minimize loss. The optimum size of DG is 7MW for the power system under study, it is concluded after studying the table VII. The voltage profile for DG with 7MW capacity is shown below.

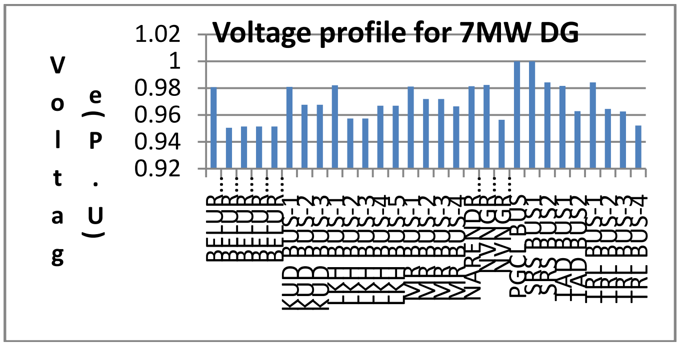

Fig -11: The voltage profile of the system after DG allocation at 3 places with 7MW capacity.

6. CONCLUSIONS

The size & location of DGs are crucial factors in the application of DG for loss minimization & voltage improvement respectively. This paper deals with a load flow based simulation using ETAP to find out the optimum location & optimum size of DG unit for voltage profile improvement & minimizing power losses in the Power System Under study. The installation of DG unit at non optimal places can result in an increase in system losses; implying in an increase in costs & resulting low or over voltages in the network, having an effect opposite to the desired. For that reason, the use of a methodology capable of analyzing the influence on some system characteristics of DG allocation can be very useful for the system planning engineer when dealing with the increase of DG penetration that is happening nowadays. The proposed algorithm is already discussed in this paper, more accurate & can identify the best location for single DG placement in order to improve the voltage profile & to minimize total power losses. The proposed method has also used to determine the optimum size & location of DG unit. Results prove that the optimum size & location of a DG can save a huge amount of power. Power system deregulation and shortage of transmission capacities have led to an increase interest in Distributed generations (DGs) sources. The optimal location of DGs in power systems is very important for obtaining their maximum potential benefits. In this paper, only optimum location of DG has been determined for loss reduction and voltage improvement in the distribution system. For proper allocation of DG, size of DG also plays an important role. Size of DG effects losses and voltage profile of the distribution system. Also a comparative study can be done between different techniques like Analytical method, Optimum power flow method, Evolutionary techniques like Genetic Algorithm(GA), Fuzzy logic etc. for finding optimum size and location of DG for loss minimization and voltage improvement of the power system.

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