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Optimal Location of DG to Improve Voltage Sag in Radial Distribution System

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Abstract—*There are many disturbance like voltage Sag, voltage swell, flicker and harmonics which affect the power quality of power system. Among them, voltage sag is one of the most important problems. This phenomenon imposes a bad effect on domestic and industrial loads, especially on sensitive ones. An alternative is use of distributed generation (DG) because of its positive impacts such as voltage support, improved reliability, small size and losses reduction, together with improving voltage sag. In this thesis wind energy (DFIG) is used, wind energy is becoming the most viable renewable energy source mainly because of the growing concerns over carbon emissions and uncertainties in fossil fuel supplies. Simulation studies are carried out in 11 bus radial distribution real system using MATLAB/SIMULINK to examine these issues during steady-state and transient operations of the system. Optimal locations and sizing of the DG are determined based on this analysis. Once the optimal DG size and location is determined then its effect on the voltage swell of the system is studied here.*

1. INTRODUCTION

Increasing population day by day results in increase in demand of electricity which gives chances of fault or disturbance increasing gradually and also affects the power quality adversely. Voltage Sag is a very important and serious problem of power quality that affects the power system. So improvement of Voltage Sag condition is necessary to maintain good power quality in system. The present work tries to improve voltage sag. For Voltage Sag improvement there are many methods in power system like DSTATCOM (Distribution Static Compensator), DVR (Dynamic Voltage Restorer), TCR (Thyristor Controlled Reactor), DG (Distribution Generation / Distributed Generation) and DVR (Dynamic Voltage Restorer).

In this work, we have used DG (Distribution Generator) because of increasing concern on oil reduction, high demanding power and environmental protection which has given increased interest in DG system. This provides a lot of benefits like increasing utilization of renewable energy, reliability and improving power quality along with support provided by them to the grid in disturbances. The more the sensitivity of the load the good quality of power supply is required. Voltage sag is a very serious problem of power quality which effects equipment safety.

There are different types of DG are available in power system like PV (Photo Voltaic cell), Fuel Cell, Diesel Generation, Micro Turbine and Wind Generation. Use of DG also improves the voltage profile of power system and increase reliability of power system.

2. METHODS FOR IMPROVEMENT OF VOLTAGE SAG

There are many methods to reduce the effect of voltage sag like:

1. DVR (Dynamic Voltage Restorer)
2. DSTATCOM (Distribution Static Compensator)
3. TCR (Thyristor Controlled Reactor)
4. DG (Distribution Generation)

2.1 DG (Distribution Generation)

DG (Distribution Generation) is a comparatively new concept in the electrical generation and it is environment friendly. The size of DG is very small scale which depends upon total load. In this work Distribution Generation (DG) has been used because DG has many advantages that are discussed below.

The types of DG are given below:

1. Renewable energy:

(a) Photovoltaic (PV)

(b) Wind Turbines

(c) Storage Energy (Batteries, Flywheels)

(d) Ocean energy

(e) Geothermal energy source

(f) Biomass energy source

2. Non Renewable Energy :

(a) Fuel Cell (FC)

(b) Micro-Turbines (MT)

(c) Diesel generator

The capacity of DG is much less than total load plus total losses. Generally the size of DG is between 10 to 40% of total load and total losses. DG has a few drawbacks like it can increase the voltage magnitude and fault level at the distribution bus but it can at the same time control the voltage sags.

So, we have chosen to connect DG in the system to improve the voltage sag condition of any existing distribution system. The most important step here is to find the optimal location of DG for voltage sag improvement. Sizing of DG is also influence on the system because when size of the DG is increase then improvement of voltage profile is improved but after the optimal size the losses of the system is increased and that is why DG sizing is also important for voltage sag improvement. The size for which the sag is minimum that corresponds to the optimal sizing of DG. The following diagram shows a radial distribution system with different DG systems connected. Only renewable source based DGs are shown here, like solar cell and wind turbines.

In present work we have considered wind turbine as the source of renewable energy and it is connected as the DG source in the test systems. The following section describes the basics and importance of harnessing wind energy in the present power market scenario.

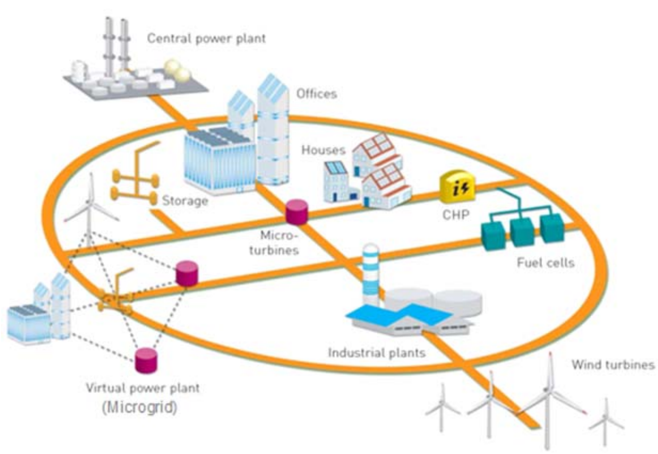

Fig. 1.1: DG in radial system

2.1.1 Advantage of DG:

The advantages of connecting DG in distribution system are as follows:

1. Reducing the network power loss.
2. Improving the network voltage profile.
3. Reducing the system components capacities.
4. Increase feeder life.

2.2 Wind Energy

The fastest growing renewable energy of power system is wind energy. Wind power is depend upon the speed of wind. Wind turbine convert kinetic energy into mechanical energy and generator convert that mechanical energy into electrical energy. In wind generation, there are widely used induction generator due to simple and maintenance free construction. Induction generator connected with turbine to generate electrical energy it is take reactive power. Type of wind energy are given:

1. WTIG (Wind Turbine Induction Generator)

2. DFIG (Doubly Fed Induction Generator)

2.2.1 Wind Turbine Induction Generator (WTIG)

The wind turbine and the induction generator (WTIG) are shown below. The stator winding is connected directly to the grid and the rotor is driven by the wind turbine. The power captured by the wind turbine is converted into electrical power by the induction generator and is transmitted to the grid by the stator winding. The pitch angle is controlled in order to limit the generator output power to its nominal value for high wind speeds. In order to generate power the induction generator speed must be slightly above the synchronous speed. But the speed variation is typically so small that the WTIG is considered to be a fixed-speed wind generator. The reactive power absorbed by the induction generator is provided by the grid or by some devices like capacitor banks, SVC, STATCOM or synchronous condenser.

2.2.2 Doubly Fed Induction Generator (DFIG)

In doubly-fed induction generator, the stator windings of DFIG through a transformerare connected to the grid (50Hz) and rotor circuit is connected through a back to back voltage source inverter system, an AC/DC/AC IGBT based converter. Inverter ratingis 25% of total power and the speed of the generator is 33% of synchronous speed.Mechanical energy is directly proportional to the wind speed.The optimum turbine speed producing maximum mechanical energy for a given wind speed. DFIG technique is the ability for power electronic converters to generate absorbs reactive power, thus eliminating the need for installing capacitor banks as in the case of squirrel-cage induction generators. The DFIG technology allow take maximum energy from the wind for low wind speeds by optimizing the turbine speed, while minimizing mechanical stresses on the turbine during gusts of wind.

The AC/DC /AC converter is divided into two parts: The grid side converter (Cg) and the rotor-side converter (Cr). CgandCr are VSC use forced commutated power electronic devices (IGBT) to synthesize an AC voltage from a DC voltage source. A capacitor connected on the DC side acts as the DC voltage source. A coupling inductor L is used to connect Cgto the grid. The three-phase rotor winding is connected to Cr by slip rings and brushes and the three-phase stator winding is directly connected to the grid. The power captured by the wind turbine is converted into electrical power by the induction generator and it is transmitted to the grid by the stator and the rotor windings. The control system generates the pitch angle command and the voltage command signals Vr and Vgc for Cr and Cg respectively in order to control the power of the wind turbine, the DC bus voltage and the reactive power or the voltage at the grid terminals.

2.3 The Wind Turbine And DFIG System

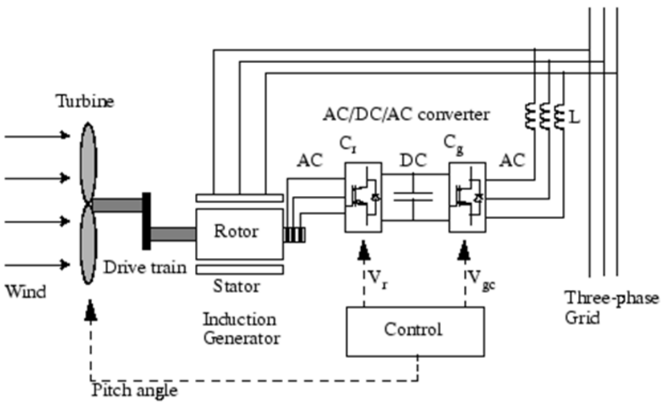

Fig. 2.3: The Wind Turbine and DFIG System

Mechanical power:

$$P_m = T_m \omega_r$$

Stator electrical power:

$$P_s = T_m \omega_s$$

Mechanical equation is:

$$J \frac{d\omega_r}{dt} = T_m - T_{em}$$

loss less generator at fixed speed in steady state:

$$T_m = T_{em}$$

$$P_m = P_s + P_r$$

$$P_r = P_m - P_s = T_m\omega_r - T_m\omega_s = -$$

$$T_m\left(\frac{\omega_s - \omega_r}{\omega_s}\right) = -sT_m\omega_s = -sP_s$$

Where, s = the slip of the generator

$$s = \frac{\omega_s - \omega_r}{\omega_s}$$

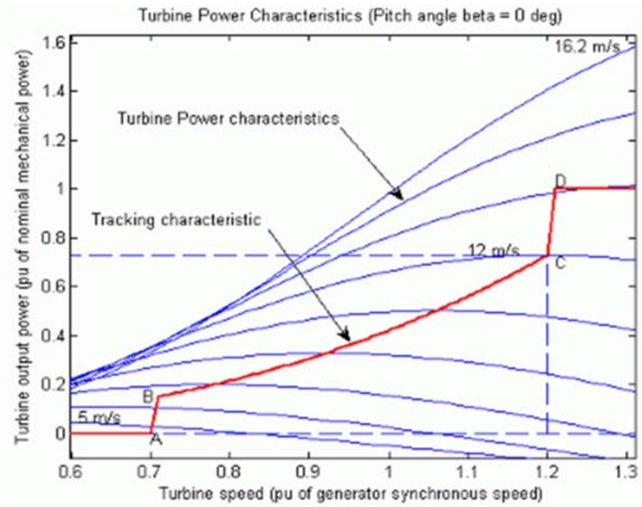

Fig. 2.3(a): Wind Turbine Characteristics

3. DATA ANALYSIS AND RESULT

3.1 Test System - Radial Distribution System

For the present work the system under consideration is a real life system. We have considered a radial distribution system from Baghdad city network (AL MansoorNo.11), this distribution system has 11 buses. The single line diagram of the system and the data are presented below:

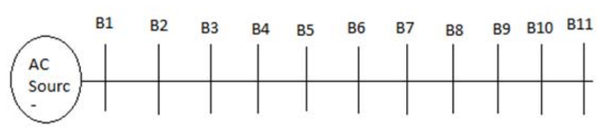

Fig. 3.1: Radial system from Baghdad city (Al Mansoor No. 11)

Nominal voltage is 11.1 KV, and connected to Baghdad city (Al Mansoor No. 11) substation. The systems are relevant data are given in two table, then base values 11 KV and 2250 KVA. Each bus has loaded by 233 KV at 0.77 power factor lagging except buses no.1 and no.4.

Table 3.1(a). Data Bus

BUS		Length in Km	R in ohm/KM	X in ohm/KM
0	1	0.450	0.124	0.106
1	2	0.150	0.330	0.350
2	3	0.200	0.330	0.350
3	4	0.025	0.330	0.350
4	5	0.250	0.330	0.350
5	6	0.100	0.330	0.350
6	7	0.075	0.330	0.350
7	8	0.050	0.330	0.350
8	9	0.100	0.330	0.350

9	10	0.035	0.330	0.350
10	11	0.150	0.330	0.350

Table 3.1(b). Load Data

BUS	Active Power(KW)	Reactive Power(KVAR)
1	0.000	0.000
2	178.711	149.504
3	178.711	149.504
4	0.000	0.000
5	178.711	149.504
6	178.711	149.504
7	178.711	149.504
8	178.711	149.504
9	178.711	149.504
10	178.711	149.504
11	178.711	149.504

3.2 Analysis Of The Voltage Profile Of The 11 Bus System:

In this work the system contains 11 bus system and 9 loads are connected. At first fault is created at the bus no. 11. The system data is given in able no.3.1 and table no. 3.2. Three phase AC source is connected at bus no.1. Three line to ground fault is considered here. The fault creates voltage sag at each bus, the value of voltage sag is more near the faulty bus and value of voltage sag is less near the AC source. All bus connected the scope which gives graph between voltage magnitudes in p.u. with respect to time.

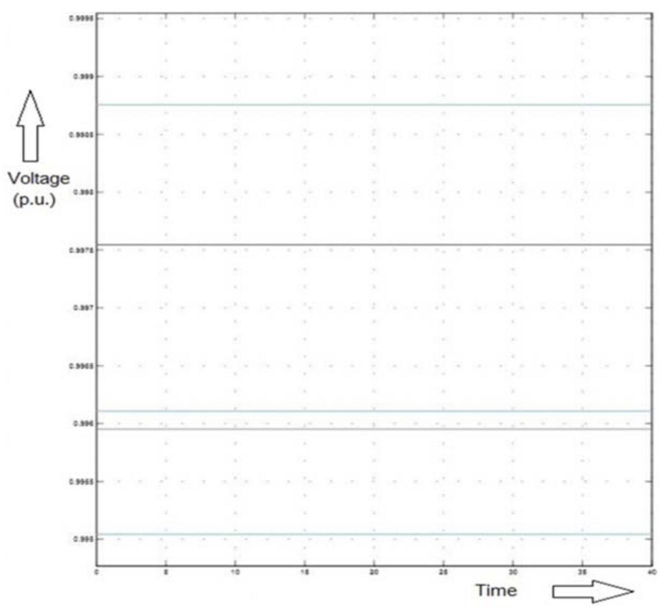

Fig. 3.2(b): Without Fault and without DG

This graph is showing voltage profiles of 5 buses of the 11 bus system.

This graph shows remaining 6 bus voltages when there is no fault in the system. This graph does not show any disturbance like voltage sag or swell as expected. The voltage magnitude at each bus given in the below (Table No. 3.2):

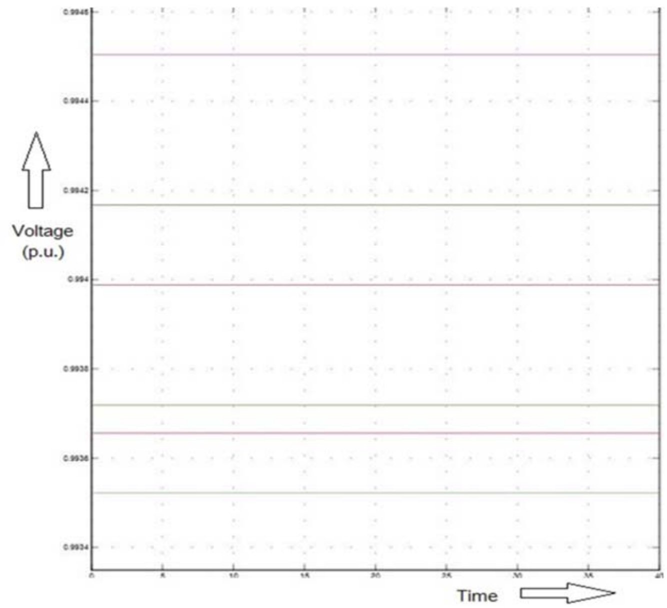

Fig. 3.2(b): Without Fault and without DG

Table 3.2: Voltage Magnitude

Bus no.	Voltage magnitude
B1	0.9988
B2	0.9975
B3	0.9961
B4	0.9959
B5	0.9950
B6	0.9945
B7	0.9942
B8	0.9940
B9	0.9937
B10	0.9937
B11	0.9935

3.3 Analysis For Voltage Sag (11 Bus System) With DG

In this simulation model fault at bus no. 11 and DG is connected at bus no.6. The power output of the DG will improved the voltage sag. The fault at bus no. 11 is three line to ground fault.

3.3.1 Wind Speed

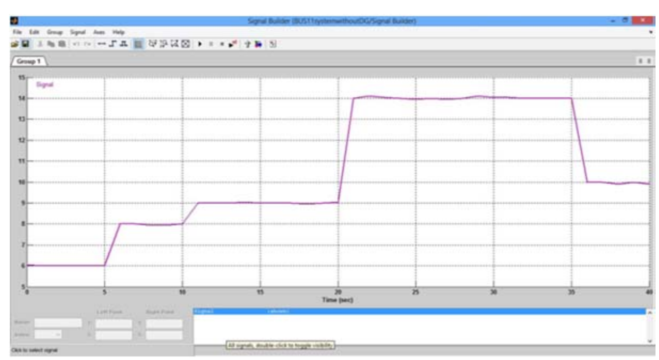

Fig. 3.3.1. Wind Speed

Wind speed varies between the speeds 6 m/s. to 14 m/s. This wind speed is used in turbine of DFIG in MATLAB/SIMULINK. The mechanical power of turbine depends upon wind speed. This mechanical power converts into electrical energy by induction generator.

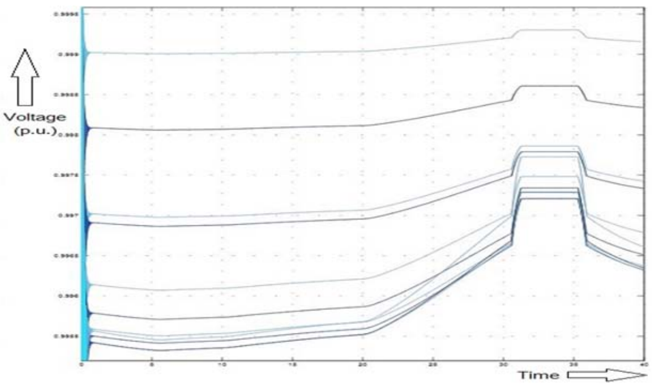

Fig. 3.3.1(a).Without Fault and with DG

This graph shows the voltage profile of all the 11 buses when DG is connected.

3.4 Fault At Bus No. 11

At bus no. 11 three line to ground fault by three phase fault model has been created and DG(DFIG) is connected at bus no. 11 in 11 bus radial distribution system by using MATLAB/SIMULATION. The voltage magnitude at each bus is taken and shown through the graph and the DG at bus no. 10 is connected which gives the voltage magnitude through the graph and then the DG is connected at bus no. 9 and voltage magnitude through the graph is taken and then DG is connected at bus no. 8 .The voltage magnitude through the graph is shown. Then DG is connected at bus no.7 and then taken voltage magnitude through the graph and the last one DG is connected at bus no. 6 and taken the voltage magnitude from the graph. Then further no need to connect the DG near the main source generator because near the source generator voltage sag is not more effective.

3.4.1 Simulation Result For Fault At Bus No.11

The graph (Fig. 3.4.1(a)) shows voltage profile of 11buses without DG and fault at 11th bus. And the graph (Fig. 3.4.1(b)) shows voltage profiles of 11 bus system when three LG fault at 11th bus occurs and DG is connected at 11th bus. The graph is initially at normal state and when three LG fault is occurring at 11th bus voltage sag takes place for 5 seconds and then voltage profile regains its normal state.

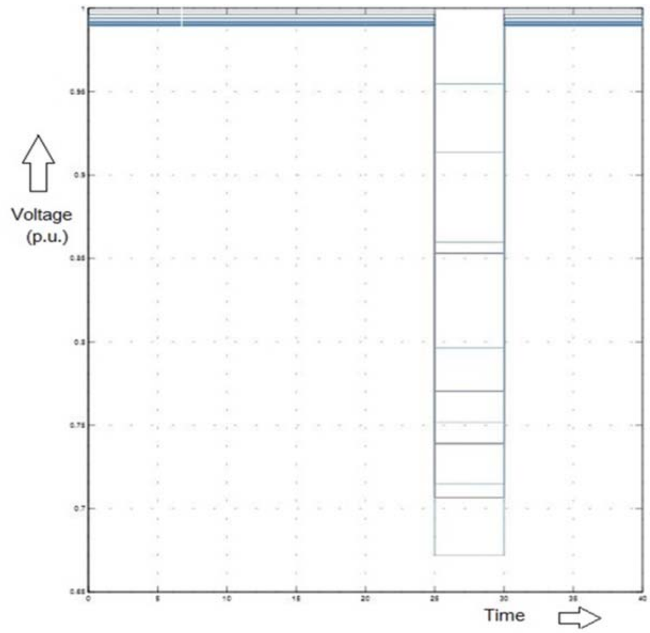

Fig. 3.4.1(a). Three LG Fault without DG

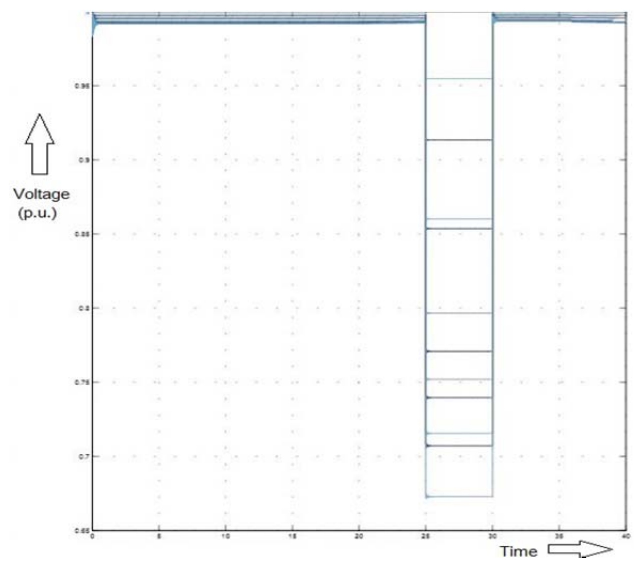

Fig. 3.4.1(b). Three LG Fault without DG

Table 3.4: Voltage Magnitude For FAULT AT BUS11 WITH DG

Bus no.	Without DG at	DG at Bus11	DG at Bus10	DG at Bus9	DG at Bus8	DG at Bus7	DG at Bus6
1	0.9546	0.9546	0.9546	0.9547	0.9547	0.9547	0.9547
2	0.9132	0.9134	0.9134	0.9135	0.9135	0.9135	0.9135
3	0.8597	0.8600	0.8600	0.8601	0.8601	0.8601	0.8602
4	0.8531	0.8534	0.8534	0.8535	0.8536	0.8360	0.8537
5	0.7963	0.7965	0.7966	0.7966	0.7967	0.7967	0.7968
6	0.7704	0.7707	0.7708	0.7708	0.7709	0.7710	0.7710
7	0.7514	0.7517	0.7519	0.7519	0.7520	0.7521	0.7520
8	0.7146	0.7151	0.7153	0.7153	0.7153	0.7153	0.7152
9	0.7146	0.7151	0.7153	0.7153	0.7153	0.7153	0.7152
10	0.7063	0.7068	0.7070	0.7070	0.7069	0.7069	0.7069
11	0.6717	0.6725	0.6724	0.6724	0.6723	0.6723	0.6723

We can study the voltage magnitude during the fault (Three LG Fault) from graph above and the voltage magnitude of each bus of without DG to with DG at bus no.11is compared and then result with DG has improved the voltage magnitude of each bus. Then comparison at each bus (11 BUS) with DG at bus no.11 to each bus (11 BUS) of with DG at bus no. 10 and then result has found to have improved the voltage magnitude of DG at bus no. 10. Then comparison of each bus (11 BUS) with DG at bus no.10 to each bus (11 BUS) with DG at bus no. 9 and result has found to have improved the voltage magnitude of DG at bus no. 9 and then comparison with each bus (11 BUS) with DG at bus no.9 to each bus (11 BUS) with DG at bus no. 8 and result has improved the voltage magnitude of DG at bus no. 8 and again following the same procedure comparison of each bus (11 BUS) with DG at bus no.8 to each bus (11 BUS) with DG at bus no. 7 and result has improved in terms of voltage magnitude of DG at bus no. 7. Then comparison of each bus (11 BUS) with DG at bus no.7 to the each bus (11 BUS) with DG at bus no. 6 and result is not better than the earlier one and so the voltage magnitude of DG at bus no. 6 is not improving and hence there are no need to further connect the DG near the source generator because far end bus voltage magnitude is not improving. So, from the above analysis it has been found out that the optimal location of the DG is at bus no.7.

3.5 Effect Of DG Connection On Voltage Swell

Once we choose the optimal location and size of DG its effect on the voltage swell when heavy load is disconnected at bus no.11 is studied here.

3.5.1 Swell for Breaker at Bus No.11

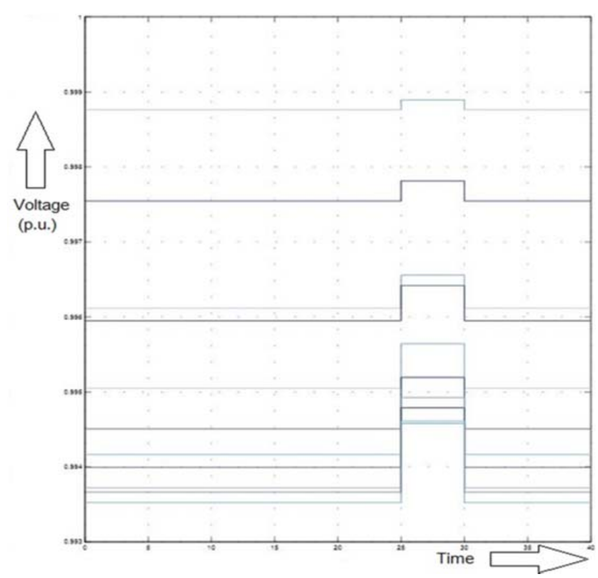

Fig. 3.5.1. Swell for Breaker at Bus No.11

This graph shows voltage profiles of 11 bus system hen load at bus no.11 is disconnected from the system. The graph is initially at normal state and when load at 11th bus is disconnected voltage swell takes place during the disconnection of load (5 seconds) and then voltage profile regains its normal state.

3.5.2 Effect of DG on Voltage Swell

This graph shows voltage profile of 11 bus system when load at bus no.11 is disconnected from the system and DG is connected at bus no.11. The graph is initially at normal state and when load at 11th bus is disconnected voltage swell takes place during the disconnection of load (5 seconds) and then voltage profile regains its normal state.

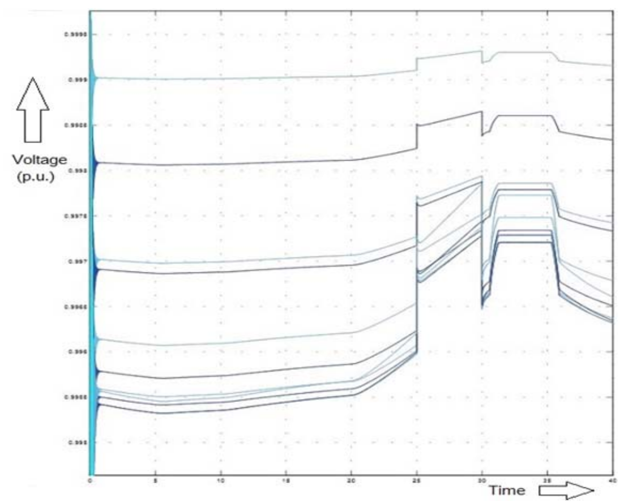

Fig. 3.5.2. Voltage Swell with DG at bus no.11

4. CONCLUSION

In this work, the optimal location and sizing of a DG is done for improving voltage sag and hen the effect of this DG on the voltage swell is studied for the 11bus radial distribution system. The main aim of this thesis is to find the optimal location of DG and sizing of DG in 11 bus radial distribution system by using MATLAB/SIMULINK.

The fault at different location of buses is created and the DG is installed at different location of buses and accordingly the analysis of simulation result of different location of buses and the optimal location of DG at bus no. 7 is found out.

In this paper, the size of DG has been changed at optimal location bus no. 7. On the basis of simulation result and comparison of the graph have been done and the optimal sizing of DG 900KW is found.

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