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Voltage Profile Improvement of Radial Feeder through Distributed Generation

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Abstract: Small scale generations connected to distribution network instead of transmission is termed as Distributed Generation (DG). DGs normally use renewable energy sources like wind and solar photovoltaic resulting in clean environment. Pakistan has great potential for wind and solar generation. Lower construction time and less initial cost make DG a suitable and quick remedy for energy crises of Pakistan. DGs alter power flows in distribution network and therefore has effects of power losses, voltage profile and short circuit level depending on the size, type a and location of the installed DG. Voltage profile is an important measure of performance of a utility. Utility equipment and consumer appliances are sensitive to voltage variations. Low voltage will decrease performance of equipment and operating life of the equipment.

In this research work, PSS SINCAL software is used for simulation analysis of 11 kV radial distribution feeder for DG impacts on voltage profile. Node voltages of existing network were observed below acceptable lower limit of -5% of rated voltage. Three DG units, each of 1 MW, are proposed to meet demands locally. Simulation results of the proposed network show considerable improvement in node voltages of both H.T and L.T networks. Node voltages are improved to lie within acceptable limit.

Keywords: Distribution system; Voltage profile; Distributed Generation; HESCO.

1. INTRODUCTION

Power sector of Pakistan is facing worst crises of its history. Demand supply gap is increasing rapidly. No serious efforts have been taken to increase generation capacity whereas power demand is increasing mainly due to increasing population and associated comfort level. It results in long duration load shedding (Sahito, *et. al.* 2014). Aged transmission and distribution result in high power losses and voltage drops, making it very difficult to supply quality power to consumers. Most of the consumers being supplied well below acceptable voltage limits (Sahito, *et. al.* 2015).

Water and Power Development Authority (WAPDA) was disintegrated to Generation Companies (GENCOs), National Transmission and Dispatch Company (NTDC) and distribution companies (DISCOs) to increase performance through better management in power sector but expected results have never been achieved due to technical and political grounds. Hyderabad Electric Supply Company (HESCO) is a distribution utility responsible for power distribution in lower part of the province of Sindh including the districts of Hyderabad, Badin, Mirpurkhas, Thatta, Matiari, Nawabshah and surroundings. It is facing problems of high technical losses, voltage regulation and electricity theft (Ghanghro, *et. al.* 2016). Different system improvement projects are under execution to improve its performance such asnew substations, sub transmission circuits and distribution feeders to improve system power handling capacity and power loss reduction.

Distributed Generation (DG) is small scale power generation mostly employing renewable energy resources and connected directly to distribution system. Renewable energy resources offer advantages of low carbon emission, sustainable energy resources, mix of fuel generation sources, fuel availability and almost zero fuel cost (Akorede, *et. al.* 2010). As DGs are connected directly to distribution system, cost of constructing long transmission lines, substations associated distribution system is reduced. Energy efficiency is increased as power is generated near utilization equipment.

Consumer appliances are designed to operate at rated voltage level and allowable lower and upper limits. If operated beyond these acceptable limits, performance of the appliances is affected and their operating life is decreased (Umer, *et. al.* 2013). Efficiency of power transmission is also decreased with reduced voltage. Researchers are working to investigate problems and causes of voltage drop, techniques to improve system performance and impacts of DG on power system performance. (Kim, 2001)analyzed impacts of DG for voltage regulation and concluded settings of voltage regulating equipment are changed with DG interconnections.(Sun *et. al.* 2009) suggested that (DG) can represent a significant impact on the distribution networks, such as system reliability, power flow, relay protection, voltage profile and stability but Voltage may increase above acceptable limits.(Uqaili *et. al.,* 2014)investigated increased short circuit levels caused by DG interconnection with radial distribution feeder.

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This paper focuses on voltage profile improvement of radial distribution feeder through DG interconnection. One of the 11kV feeder from HESCO network is selected for analysis. Actual network data for selected feeder is used for simulation using Power System Simulation Siemens Network Calculator (PSS SINCAL) software. Simulation results are analyzed for bus voltages of the existing system. Three DG units of 1 MW each are suggested at physically viable locations and modified network is simulated to observe improvement in bus voltages.

Section 2 of the paper describes voltage profile andcauses of the voltage drop. DGs are also described in this section with their types. Concept of voltage profile improvement through DG interconnection is also discussed in this section. Selected feeder and its network structure is given in section 3. Simulation results of the existing and proposed systems are discussed in Section 4. Results are compared to observe impacts of DG interconnection for voltage profile improvement. Finally paper is concluded in section 5.

2. VOLTAGE PROFILE IMPROVEMENT THROUGHDISTRIBUTED GENERATION

Voltage level supplied at consumer terminals is an important measure of utility performance and consumer satisfaction. Load current (I) flowing through distribution lines and transformers cause voltage to be dropped as given as:

$$V.D = I.Z \quad (1)$$

Where Z is impedance of the line or transformer.

Radial distribution feeder is most commonly used configuration because of simplicity and low cost. Load is distributed through the length of radial feeder. Voltage is dropped in all sections of the radial feeder due to current flowing. Node voltage is reduced as distance of the node increases from source. Voltage is improved using voltage regulating equipment such as tap changer of the transformer and shunt capacitors installed to compensate for reactive power requirements of the loads (Deilami *et. al.* 2014).

DG refers to power generation distributed on different locations. Maximum generation capacity of DG units differs in definitions given by different agencies but they all agree that DG is connected to distribution system unlike conventional generation sources. DG power limit given by International Counsel for Large electricity Systems is 100 MW whereas Electric Power Research Institute (EPRI) considers DG to be less than 50 MW (Wolsink, 2012).

DG technologies include solar photovoltaic cell, wind turbines, micro turbines, reciprocating engines, fuel cells, combined heat and power (CHP) and bio mass. Use of renewable energy resources results in environment friendly generation. Unlike conventional thermal power plants, DGs can be installed within populated areas near the load centers because of pollution free generation. As DGs fulfils power demand locally, expensive system expansion for transmission and distribution network can be avoided. Additionally power losses may also decrease due to changed power flows (Uqaili *et. al.*, 2014).

Pakistan has great potential for renewable energy resources specially wind and solar generation. Wind generation potential in coastal areas of Sindh and Baluchistan is capable of meeting the country's power demands (Harijan *et. al.* 2011). Some of the wind generations such as Jahmpir wind farms are already supplying power to HESCO. Wind generation uses different generators like synchronous, induction and double feed induction generator (DFIG).Synchronous generators offer supply both active and reactive power whereas other two types need shunt capacitors to be installed for reactive power requirements.

(Fig. 1) shows concept of radial distribution feeder showing decreasing voltage along the feeder length. When a DG is installed at the end of the feeder, power flows are altered and thus voltage near the DG is increased. Therefore voltage below lower acceptable limit is increased and thus all the feeder consumers are supplied within acceptable voltage limits.

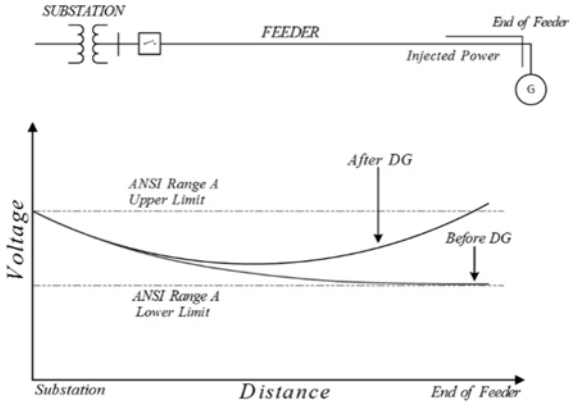


Fig. 1: DG impact on voltage profile of radial distribution feeder

3. SYSTEM DESCRIPTION

11kV Preetabad-I feeder of HESCO is selected for this research work. It is energized from HALAROAD substation and supplies residential, commercial and pumping consumers of the Preetabad and surrounding areas in Hyderabad city. 6.605 MVA power capacity of 47 distribution feeders is energized through 47 distribution transformers. (**Fig. 2**) shows node diagram of the selected Preetabad feeder.

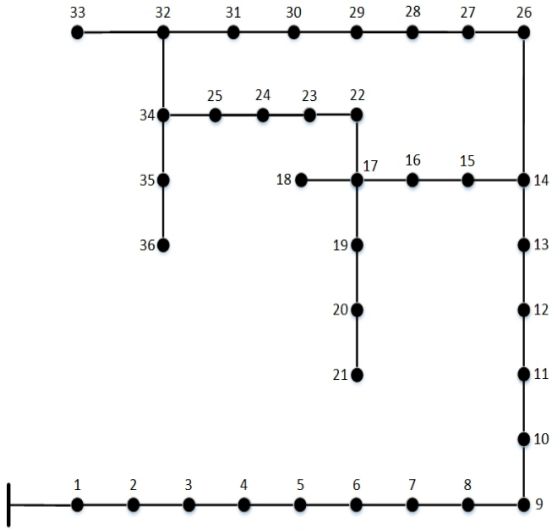


Fig. 2: Node diagram of Preetabad feeder

Actual data for high tension (H.T) and low tension ((L.T) networks of the selected feeder were calculated through field visits in coordination with HESCO staff. Collected data included length of different sections of H.T. lines, conductor type, transformer ratings, transformer impedance, L.T network lengths, conductor types and number of connections. Average loads are assumed for residential and commercial consumers. Loads of the pumping stations are selected by connected loads. Three DG units each of 1 MW and 0.7 MVAR capacity are proposed at nodes 12, 17 and 29. Network is modelled and simulated with and without DG units to observe impact of DG on voltage profile of the selected feeder.

4. RESULT DISCUSSION

(**Table 1**) shows voltage comparison of the H.T nodes with and without proposed DG units. It is clearly shown that voltage of all the buses have improved considerably. Percentage increase in bus voltages for buses near the source is small as DGs are installed away from these nodes. Appreciable increase is observed at nodes 17, 29 and near to these nodes where DGs are installed. Node voltage of last two buses 34 and 36 have increased from 10.03 kV to 10.81 kV indicating an increase of 0.78kV. All the bus voltages are now within acceptable lower limit of -5%.

(**Table 2**) shows voltage comparison of the L.T terminals of 47 transformers. It is clear that node voltages have improved considerably. All the transformers have L.T terminal voltage within acceptable limit of -5%. Highest percentage rise of 10.70% is observed for transformer 26 located at node 18, which is located at the end of a branch circuit. DG proposed at node 17 is responsible for this rise in voltage.

Table 1. H.T node voltage comparison with and without DG

Node	Voltage (kV)		Rise in Voltage	
	Without DG	With DG	kV	%
1	10.97	10.99	0.02	0.18%
2	10.90	10.97	0.07	0.64%
3	10.88	10.97	0.09	0.83%
4	10.76	10.93	0.17	1.58%
5	10.68	10.91	0.23	2.15%
6	10.66	10.91	0.25	2.35%
7	10.51	10.88	0.37	3.52%
8	10.38	10.86	0.48	4.62%
9	10.23	10.85	0.62	6.06%
10	10.21	10.84	0.63	6.17%
11	10.11	10.83	0.72	7.12%
12	10.08	10.83	0.75	7.44%
13	10.07	10.83	0.76	7.55%
14	10.06	10.83	0.77	7.65%
15	10.05	10.83	0.78	7.76%
16	10.05	10.83	0.78	7.76%
17	10.04	10.83	0.79	7.87%
18	10.04	10.82	0.78	7.77%
19	10.04	10.82	0.78	7.77%
20	10.04	10.83	0.79	7.87%
21	10.04	10.82	0.78	7.77%
22	10.03	10.82	0.79	7.88%
23	10.03	10.82	0.79	7.88%
24	10.07	10.83	0.76	7.55%
25	10.07	10.83	0.76	7.55%
26	10.06	10.83	0.77	7.65%
27	10.06	10.83	0.77	7.65%
28	10.05	10.83	0.78	7.76%
29	10.05	10.83	0.78	7.76%
30	10.04	10.82	0.78	7.77%
31	10.04	10.82	0.78	7.77%
32	10.03	10.82	0.79	7.88%
33	10.03	10.82	0.79	7.88%
34	10.03	10.81	0.78	7.78%
35	10.03	10.81	0.78	7.78%
36	10.03	10.81	0.78	7.78%

Table5. Load unbalance at transformers of 11kV Hayat feeder

Transformer			Voltage (kV)		Rise in Voltage	
Sr.	Node	kVA	Without DG	With DG	kV	%
1	1	200	389.84	390.72	0.88	0.22%
2	2	25	394.5	397.41	2.91	0.74%
3	3	200	372.55	375.97	3.42	0.92%
4	4	200	389.14	395.95	6.81	1.75%
5	5	200	389.03	398	8.97	2.31%
6	6	25	384.94	394.58	9.63	2.50%
7	7	25	385.53	399.85	14.32	3.71%
8	8	100	376.56	395.39	18.83	5.00%
9	9	630	369.92	393.97	24.05	6.50%
10	10	100	368.28	393.27	24.99	6.79%
11	11	50	358.61	387.87	29.26	8.16%
12	11	100	362.91	391.84	28.93	7.97%
13	13	25	361.97	392.05	30.08	8.31%
14	14	400	365.88	396	30.12	8.23%
15	15	100	366.89	397.3	30.41	8.29%
16	15	200	360.95	391.85	30.9	8.56%
17	16	200	366.12	396.58	30.46	8.32%
18	20	200	361.9	393.03	31.13	8.60%
19	21	200	357.73	389.63	31.9	8.92%
20	21	25	357.66	389.28	31.62	8.84%

21	22	25	357.13	389.5	32.38	9.07%
22	23	100	355.49	387.2	31.71	8.92%
23	23	25	355.49	387.2	31.71	8.92%
24	17	200	353.68	385.27	31.59	8.93%
25	17	200	353.08	384.73	31.65	8.96%
26	18	200	344.06	380.89	36.83	10.70%
27	19	25	355.61	387.35	31.74	8.93%
28	24	50	359.74	390.3	30.55	8.49%
29	25	25	360.12	390.59	30.48	8.46%
30	26	200	357.82	388.9	31.09	8.69%
31	26	200	350.31	385.73	35.42	10.11%
32	26	200	353.79	384.88	31.09	8.79%
33	27	200	354.15	385.43	31.28	8.83%
34	28	200	358.95	389.91	30.96	8.63%
35	29	100	379.09	408.57	29.48	7.78%
36	30	25	367.54	397.96	30.42	8.28%
37	31	25	353.38	385.23	31.86	9.01%
38	35	100	355.39	386.84	31.45	8.85%
39	35	200	373.95	403.82	29.87	7.99%
40	35	200	358.13	389.33	31.2	8.71%
41	36	200	350.21	382.61	32.4	9.25%
42	37	200	365.35	395.98	30.63	8.38%
43	33	200	369.97	400.21	30.25	8.18%
44	33	50	343.52	376.31	32.79	9.54%
45	34	50	372.77	402.74	29.97	8.04%
46	34	100	366.48	397	30.52	8.33%
47	34	100	368.88	399.16	30.28	8.21%

5. CONCLUSION

In this paper, one of the 11 kV feeder supplying residential, commercial and pumping consumers in Hyderabad city is surveyed, modelled and simulated using PSS SINCAL software to observe impacts of distributed generation on voltage profile. Node voltages below accepted level of -5% are observed through simulation results of existing network. Three DG units of 1MW and 0.7 MVAR are proposed at physically suitable locations to meet load demands locally. Simulation results of modified network shows considerable improvement in voltages for all H.T and L.T nodes. Maximum of 8.87% voltage rise is observed for H.T nodes and 11.70% for L.T nodes. Voltages of all the buses are improved above lower acceptable limit of -5%.

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