Impact of Distributed Generation on the Quality of Power Supply in Nigeria; Port Harcourt Network Case Study

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Abstract **- This paper considered the impact of Distributed Generation (DG) on the quality of electricity supply in Port Harcourt Network. It gives account on its impact on both the present and the future load demand. Power flow analysis and Continuation Power Flow (CPF) optimization method was used to achieve the simulation. DGs were gradually dispersed among the buses to ascertain the impact of the dispersion of DGs at different buses. Only thirteen buses were considered because that is the number of DGs under construction in Port Harcourt, Nigeria, which is about 18.89% of the buses (69 bus Network). The simulation was done using MATLAB 7.9 Power System Analysis Toolbox (PSAT) simulink environment to analyze the Network. The result shows that the dispersion level of DGs among the buses increases, there is a very remarkable improvement in the voltage profile, real and reactive power and loadability of the Network. Also, since 10MW and 25MW gas turbines were considered, the dispersion base on the size of the DGs were also considered, with different arrangement of the DG sizes can also affect the behaviour of the Network. This shows that DG have a very great impact on the improvement of the Network and being proposed to the larger Nigerian Network.**

Keyword: Distributed Generation, Voltage stability, Continuation Power Flow, Power flow, voltage profile, voltage violation

I INTRODUCTION

The electrical utility is probably the largest and most complex industry in the world. The electrical engineer, who researches in this industry will encounter challenging problems in designing future power systems to deliver increasing amounts of electrical energy in a safe, clean and economical manner [1].

A recent statistics on use of generating sets in the country released by the Director-General of Centre for Management Development, Dr. Kabir Usman, revealed that about 60 million Nigerians spent N1.6 trillion on generators annually [2]. The endemic power crisis came as a result of the inability of the existing plants to meet the ever increasing demand. The supply-demand gulf exist because of myriads of reasons: obsolete and dilapidated plants with 36% of installed capacity being over 20 years old; 48% are over 15 years old and 80% are over 10 years old [3]. Other factors include lack of and poor maintenance of existing plants and poor managerial efficiency. The country's current power generation capacity fluctuates around 3,800MW and 4,500MW and the per capita electricity usage is 136 kilowatt/hour. Nigeria's electricity consumption on a per capita basis was among the lowest in the world when compared with the average per capita electricity usage in Libya, 4,270kWh; India, 616kWh; China, 2,944kWh; South Africa, 4,803 kWh; Singapore, 8,307kWh; and the United States, 13,394kWk [4]. By comparison, South Africa, with a population of just 50 million, has an installed electricity generation capacity of over 52,000 MW. On a per capita consumption basis, Nigeria is ranked a distant 178th with 106.21 KWh per head, – well behind Gabon (900.00); Ghana (283.65kWh); Cameroon (176.01kWh); and Kenya (124.68kWh) [5].

The current power system of Nigeria is undergoing major changes from the centralized generation to the decentralized. The advances in technology have created rapid growth in the utilization of distributed generation which leads to energy market becoming more attractive and competitive. As distributed systems continues to expand in Nigeria, there will be need to supplement the existing network with other means of supply which distributed generations is a better option. Over the years it has not been considered due to the DGs as at then was very low to create an impact in the existing grid. With the production of a high penetration gas turbine DGs, it will be very relevant to introduce it into the network to boost the existing network in order to meet the demand of power in the country. This is why this paper concentrates on the impact of DGs on the power quality in Nigeria using Port Harcourt Network as a case study.

II REVIEW ON IMPACT OF DG ON POWER SYSTEM STABILITY

So many works have been considered on the impact of DGs on voltage stability, of which . [6] and [7] considered DGs as the source of modern grid supply. The concluded that since DGs provide electricity closer to the customers, it can help to reduce the demand at peak times and minimize power congestion.

Warren et al [8] considered the advantages and disadvantages of DG for radial Networks and DG allocation. The author used probabilistic technique in allocating the DGs to radial Network.

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Philip [4] looked at the impact of DG on losses. The authors concluded that locating DGs on the feeders reduces losses but failed to analyze the optimal location of DG on te feeder.

Salim and Ramos [6] studied the characteristic of distribution system with DG for voltage stability. A power flow study was presented for voltage stability analysis under unbalanced condition, but the impact of system dynamics on voltage stability was not investigated.

A Review of the Port Harcourt Network

Port Hacourt Metropolis is a large city in the south-south geo political zone of Nigeria. It is the fastest growing city within the region in view of the oil exploitation and exploration activities in the area, hence the astronomical rate of growth in its load demands. This is notwithstanding the challenges of handling electricity distribution business here. We cannot really discuss the power distribution network as regards Port Hacourt in isolation from the prevailing shortfall in national power generation as the city still benefits from the national grid. Presently there is a clear mismatch between generation availability and load demand nationwide. Thus the current strict load shedding regimes that are observed .There are two numbers of transmission load centers in Port Harcourt complex (Port Harcourt mains and town) with a total installed capacity of 222.5MVA while the total peak loads are 106.5MW (day) and 127.7MW (night) respectively. These were obtained under system/generation limitations. Total availability from the independent power producers (IPP) or distributed generation averages 60MW daily that is supplied to Port Hacourt metropolis. This distributed generation (IPP) includes Omoku and Trans-Amadi and Eleme. They all have their challenges to overcome. Outside the generation limitations transmission constraint, and distribution inadequacies; the actual load demand should be in the vicinity of 361.9MW. Now, a gap of about 233.9MW approximately, which exists presently must be bridge.

In Port Harcourt metropolis, the installation distribution capacity is 444.5MVA on 33kV which translates to 355.6MW at operating power factor (PF) of 0.8. Of course, the 33kV and 11kV distribution networks have not yet attained a state of perfection. After the simulation the proposed Network was gotten which is given in figure 1

III DG PLACEMENT PROBLEM FORMULATION

The two major factors considered in placing DGs in a network are the percentage DG level and the percentage dispersion of the DGs in the network. The percentage DG level accounts for the amount of DG against the power demand,

$$\%DG\ level \frac{P_{DG}}{P_{load}} \times 100\% \qquad (1)$$

where P_{DG} is the power supply from the DG unit while P_{load} is the load demand of the area considered. For this paper, the penetration level of the DGs was assumed to be total of 280MW which is about 70% of the present total load demand of the area without grid supply.

The percentage dispersion of DGs accounts for how DGs are spread among buses depending on the number of buses or nodes.

$$\%DG\ dispersion = \frac{Number\ of\ DG\ buses}{Number\ of\ laod\ buses} \times 100\% \qquad (2)$$

This is to say that when we have 100% dispersion means that all the DGs are attached to all buses. This scenario is applicable when only DGs are used to power the network and also for a smaller networks. For this thesis, it was assumed that due to the large bus network considered, the number of maximum bus attachment is only thirteen (13) buses or nodes as at against sixty nine (69) buses or nodes which is about 18.84% dispersion network. This is done to match the available ongoing DGs installations that can be gotten in PortHarcourt.

After the candidate buses are selected, allocating DG units within the system requires investigation in terms of DG resources and their uncertainties. It also requires modeling the types of load and their criticality at each bus. In addition, placing the DG units in the most sensitive buses might violate the voltage limits or the capacity of the feeders, depending on the size of the DG units and the load demand of the system. Accordingly, this section proposes a method to place DG units with an objective of improving the voltage stability of the system. This study was demonstrated in fourteen scenarios which depends on the sizes and dispersion of the DGs.

A DG placement optimization formulation

The DG placement and sizing, with an objective of increasing the voltage stability margin, can be formulated by increasing the voltage of the system using DG units. Equation (2) is used to improve the voltage profile of the system, thus, it can be used to improve the voltage stability margin of the
system.

Table 1: DG placement result

DG placement	Voltage violation	Collapsed voltage violation	Power loading (pu)	Real power losses (pu)	Reactive power losses (pu)	Collapse real power losses (pu)	Collapse reactive power losses (pu)
No DG placement	66	-	-	0.2162	-	3.2769	-
1	53	-	-	0.25767	-	3.0856	-
2	44	-	-	0.25817	-	2.29815	-
3	31	-	-	0.28917	-	2.9512	-
4	31	-	-	0.23733	-	2.5886	
5	25	-	-	0.22769	-	2.4417	-
6	19	14	0.89016	0.07234	0.89228	0.04918	0.80794
7	10	11	1.2608	0.02473	0.28334	0.05045	0.679
8	10	11	1.3755	0.06619	0.75445	0.0501	0.6465
9	7	9	1.3727	0.03143	0.39716	0.06881	0.97185
10	7	14	1.3757	0.03162	0.37588	0.07069	0.94939
11	7	8	1.4138	0.06819	0.8058	0.05698	0.77069
12	7	9	2.1969	0.06458	0.73941	0.13943	1.6924
13	5	7	2.0949	0.01774	0.2651	0.10361	1.1758

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$$V_n \frac{V_{P with\ DG}}{V_{P without\ DG}} \qquad (3)$$

- $V_n > 1$: DG units will worsen the voltage profile
- $V_n = 1$: DG units will not impact on the voltage profile
- $V_{index} < 1$: DG units will improve the voltage profile *index V*
- $\lambda max > 0$: DG unit will improve the maximum loading factor λ_{max}

The constraints considered are the power flow equations, branch current equation, slack bus voltage and angle (the slack in this system is assumed to be bus 1), voltage limits at the other buses, feeder capacity limits, maximum penetration on each bus, maximum penetration of DG units on the system, candidate buses and discrete size of DG units:

IV RESULTS

The result shows the voltage violation, real and reactive power losses for both power flow analysis and continuation power flow analysis. Also, the result for the maximum power loading is also shown in Table 1.

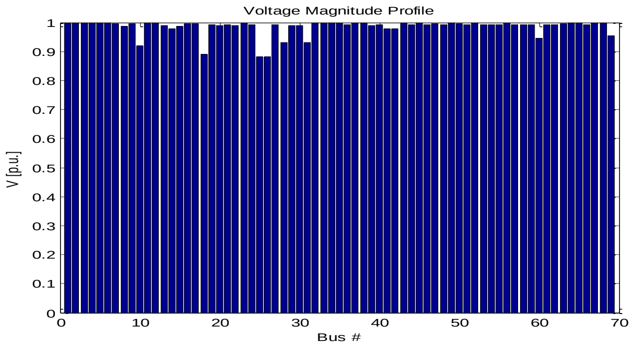

Fig 1: Voltage profile for thirteen DG placement

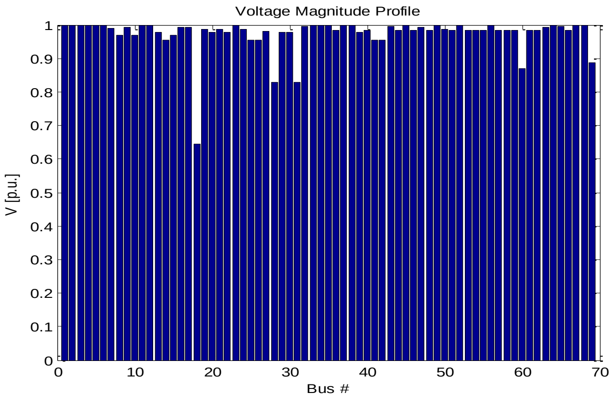

Fig 2: Voltage profile at collapse point for thirteen DG installation

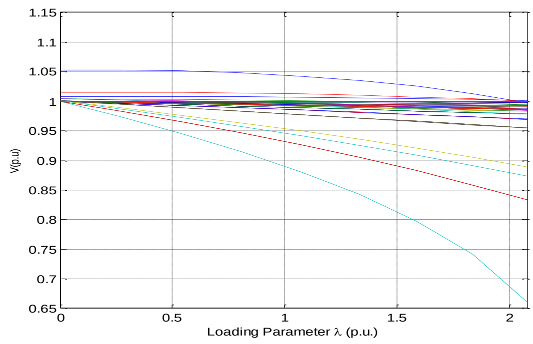

Fig 4: P-V curve for thirteen DGs dispersion

A Result discussion

The simulation for power flow and CPF was done and the voltage violations, real and reactive power losses and loading parameter for both cases and can be seen in Table 1. From the result, which gave account of the dispersion level of the DGs, it is clear that there is a greater violation of 66 buses, which is about 96% of the buses, and greater losses when DG is not added to the Network. There is a remarkable improvement as the DGs are gradually dispersed to the load centers. The greatest improvement is seen when the DGs are dispersed to thirteen buses which is about 19% of the total buses. At this point, the number of voltage violation is 5 buses, real power loss of 0.01774pu and reactive power loss of 0.2651. at the collapse point, the voltage violation is 7 buses, real power loss is 0.10361pu, reactive power loss is 1.1756pu and 2.0949pu (209.49MW) load can still be added to the Network before collapse as shown figure 1 – 3 and table 1.

Also, considering the result for the dispersion of the different DGs in thirteen buses considering the different available sizes of the DGs as shown in table 2, it is clear that attaching the DGs to 2(25MW), 3(25MW), 4(25MW), 5(25MW), 6(25MW), 7(25MW), 8(25MW), 10(25MW), 11(25MW), 12(25MW), 13(10MW), 14(10MW), 19(10MW) has the best voltage violation and collapse voltage violations of 5 buses, real power loss of 0.01086pu, reactive power loss of 0.19665, collapse real power loss of 0.10293, collapse reactive power loss of 1.1063pu and 2.5796pu (257.96MW) of power can be added to the Network before collapse.

V CONCLUSION

The work done thoroughly shows the impact of DGs in the improvement of power supply in Port Harcourt Network which can be recommended for the Nigerian Network at large. It also shows that the arrangement of the DGs in the Network can greatly affect the behaviour of the Network and its performance. From the analysis done for the Port Harcourt Network, it can be recommended that the DGs not to be installed in a particular location, but to be dispersed with the sizes at PH Z2 (25MW), PH Z4 (25MW), T1A (Z2) (25MW), T2A (Z2) (25MW), T3A (Z2) (25MW), T1B (Z4) (10MW), T1A (Z4) (10MW), T2A (Z4) (10MW), Rumuodomaya (25MW), Rumuola feeder (25MW), Oyigbo (25MW), Trans-Amadi (25MW) and Onne feeder (25MW) for better performance.

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