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Online Contingency Analysis of Port Harcourt Network in the Presence of Distributed Generation

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Abstract* - This paper considered the online contingency analysis of Port Harcourt Network in the presence of Distributed Generation (DGs) for proper management of the Network. This was done to know which lines to be more careful with and also to see the effect of off-grid electrification (removing some of the area from the grid and supplying them with the DGs). This analysis was done using MATLAB Power System Analysis Toolbox (PSAT) simulink environment. The analysis was done on 69 Port Harcourt Bus Network with two generating station (without DGs) and when 13 DGs (proposed Network) of 25MW and 10MW dispersed among 13 Buses which is 18.84% dispersion. The result gotten shows that removing some lines will result to a great effect in the Network, of which the greatest effect was seen when line 1-2 was opened. Off-grid electrification proffers a very great advantage to the Network. The result shows that Opening the line connecting from T2A (Z2) to Akani, this disconnects those fed by Akani, to only be fed by the 10MW gas turbine from Trans-Amadi, proffers the best network base on the minimal voltage violations and low real and reactive power losses. This shows that for a better performance, using off-grid electrification will be more efficient than to attach DGs directly to the Network.

Keywords: *Distributed Generation, Voltage violation, Contingency analysis, load flow, losses.*

I INTRODUCTION

Nigerian power system has been a very big concern over the years due to so many problems associated with it. Though so many suggestions have been proposed on how to stabilize the Network, the Network is still not able to satisfy the nation. This is as a result of poor generation, weak transmission lines, political issues, more loads added daily, etc. The recent supply is not enough to satisfy the demand of the customers due to low supply and dependency on the natural resources which is not enough. To counter this problem, it will be wise to shift to other sources of supply, like the Distributed Generation.

Since the integration of DG has increased to a high penetration level, and the impact of DGs on the voltage stability margin has become significant, it will be wise to investigate its impact on the Nigeria network. To achieve this, a subsection of the network is considered to see the effect of the penetration of the DG in both the centralized grid and using it as off grid electrification (cutting out some lines in that grid and just supplying them with the DG). The network considered is the Port Harcourt network.

Port Harcourt (PH) is situated in the south-eastern area in Nigeria. Port Harcourt, though a small town, its network was chosen due to the high industrialization and the increasing demand of electricity by these industries in this area. Major industries like the oil industries with high electricity consuming equipments are found in this area of Nigeria. It shows that there is every tendency for the electricity consumption or demand of the area to double the actual demand in few years to come. The problem arising is how to maintain the DGs and also dispatch it effectively which is the main focus of this paper. To achieve this it will be proper to conduct an online contingency analysis on the proposed Network in the presence of DGs. This analysis is not just to know the effect of fault, but to also know the effect of off-grid electrification (some grid cut out of the Network and supplied with DG).

II LITERATURE REVIEW

Distributed generation (DG) has become an increasingly important source in the modern power grid. Although the cost of installation is high, DG benefits the customers by providing electricity endemic to the customer rather than at a distant generator. Therefore, DG can help to reduce the demand at peak times so that power congestion may be minimized preventing degradation of service. Yet, research efforts reveal that there are challenges that DG poses to the safe and reliable operation of distribution systems [1].

To provide optimal reliability to customers, in case of multiple contingencies, the meshed low-voltage (LV) secondary networks are applied to major metropolitan areas and business districts. There is more effort involved in interconnecting DG with meshed networks compared to radial ones since the operation strategies are different [2] [3]. For instance, in meshed networks the reverse power flow from LV networks to medium-voltage (MV) networks is forbidden, which means the network protection will be tripped if the power flows from secondary side to primary side. Significant research effort has been invested in elucidating the advantages and disadvantages of DG for radial networks [4], but there is a very limited amount of work in meshed networks [5] [6].

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III METHODOLOGY

The method considered for the contingency analysis is a load flow method. In this method, load flow analysis was adopted using Newton-Raphson method considering the removal of line which might also result to off-grid electrification. This is not just to check the effect of fault on the Network, but to also verify if there will be any advantage removing some of the area of the Network from the grid and supply them with DGs. MATLAB Power System Analysis Toolbox (PSAT) was used to analyze the Network which proves to be the best tool for power system analysis.

A Computational procedure for Newton-Raphson load flow method

The computational procedure for Newton-Raphson method using polar coordinates is as follows;

Form Y_{bus}

Assume initial values of bus voltages and phase angles for load buses and phase angles for PV buses. Normally we set the assumed bus voltage magnitude and the phase angle equal to slack bus quantities [7].

Compute P_i and Q_i for each load bus from the following equations

$$P_i = \sum_{k=1}^{n} (V_i V_k Y_{ik}) \cos(\delta_i - \delta_k - \theta_{ik}) \quad (1)$$

$$Q_i = \sum_{k=1}^{n} (V_i V_k Y_{ik}) \sin(\delta_i - \delta_k - \theta_{ik}) \quad (2)$$

Compute the schedule errors ΔP_i and ΔQ_i for each load bus from the following relations

$$\Delta P_i = P_{i(sp)} - P_{i(cal)} \quad i = 1, 2, 3, \dots, n, \quad (3)$$

$$\Delta Q_i = Q_{i(sp)} - Q_{i(cal)} \quad i = 1, 2, 3, \dots, n, \quad (4)$$

For PV buses, the exact values of Q_i is not specified, but its limits are known. If the calculated value of Q_i is within limits, only ΔP_i is calculated. If the calculated values of Q_i is beyond limits, then an approximate limit is imposed and ΔQ_i is also calculated by subtracting the calculated value of Q_i from the approximate limit. The bus under consideration is now treated as a load bus (PQ).

Compute the elements of the Jacobian matrix $\begin{bmatrix} H & N' \\ M & L' \end{bmatrix}$ using the estimated $|V_i|$ and δ_i from (2).

Obtain $\Delta|V_i|$ and $\Delta\delta_i$ from equation

$$\begin{bmatrix} \Delta P \\ \Delta Q \end{bmatrix} = \begin{bmatrix} H & N' \\ M & L' \end{bmatrix} \begin{bmatrix} \Delta\delta \\ \frac{\Delta V}{V} \end{bmatrix} \quad (5)$$

Using the values of $\Delta|V_i|$ and $\Delta\delta_i$ calculated in (6), modify the voltage magnitude and phase angle at all load buses by the equations

$$V_i^{(r+1)} = V_i^{(r)} + \Delta V_i^{(r)} \quad (6)$$

$$\delta_i^{(r+1)} = \delta_i^{(r)} + \Delta\delta_i^{(r)} \quad (7)$$

The next iteration cycle is started at (2) with theses modified voltage and angle.

Continue until the schedule errors of real and reactive powers are within a specified tolerance.

Calculate the line flows and power at the slack bus.

B The Port Harcourt Network

The Port Harcourt network comprise of 69 buses of distribution along the south-south location in the Nigerian map. It gets supply basically from Afam and Ahoada which is about 220MVA (176MW) of power supply which is not enough to stabilize the demand of the state. The estimated load demand of Port Harcourt is 400MW (Port Harcourt DISCO 2015), and the ongoing works in the state is how to use the large gas turbine (DG) generators to stabilize the demands of power in the state. At Omoku, 6 gas turbines are situated there which generates 25MW of power each (total of 150MW of generation), and at Trans-amadi, 4 gas turbines generating 25MW and 3 gas turbines generating 10MW of power (total of 180MW of generation). The total power to be gotten from the ongoing reforms is 330MW of power to boost the existing 176MW of power.

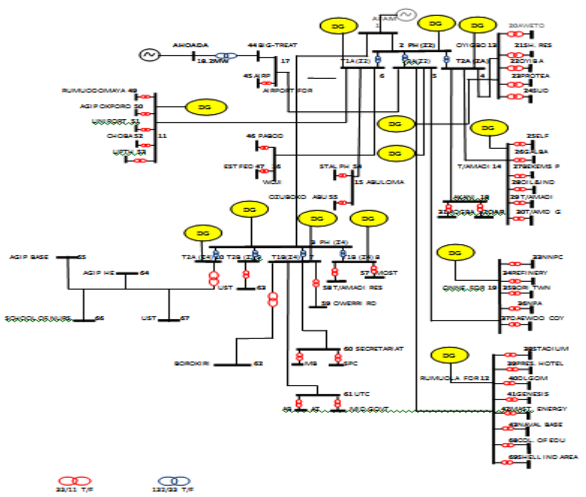

Fig 1: Port Harcourt Network with DG

IV RESULTS

After the simulation, the voltage violation, real and reactive power losses was gotten for without DGs installation, installation of DGs and the removal of line contingency analysis.

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Table 1: Removal of lines contingency analysis on the proposed network

Lines	Voltage violation	Real power losses (pu)	Reactive power losses (pu)
Without DG	66	0.2162	3.2769
Proposed Network	5	0.01086	0.19665
1-2	17	33.5384	337.4358
2-6	14	95.4538	480.3785
3-7	8	0.0907	1.28488
3-8	10	0.1127	2.15489
4-14	6	0.0955	1.0103
4-18	4	0.03404	0.3605
6-15	6	0.07	0.70519
18-31	5	0.03944	0.43077
19-33	5	0.07063	0.79242
19-34	6	0.06802	0.75327
19-37	6	0.06802	0.75327

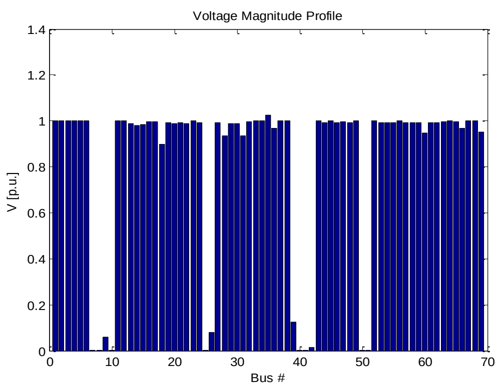

Fig. 2: Removal of line 1-2 for the proposed network

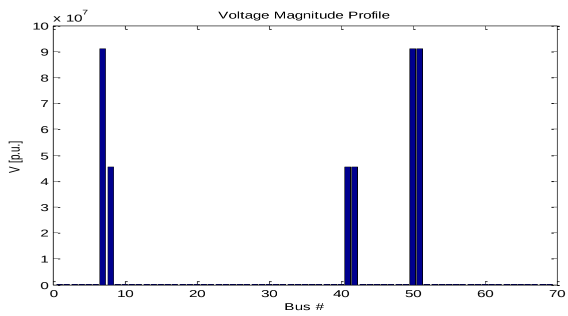

Fig. 3: Removal of line 2-6 for the proposed network

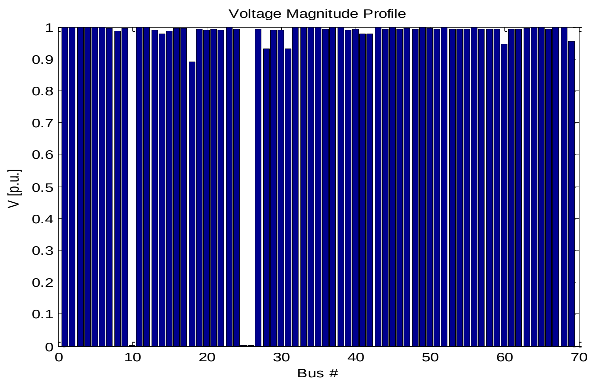

Fig. 4: Removal of line 4-18 for the proposed network

A Result discussion

Online contingency analysis was carried out on the proposed network to ascertain the effect of line removal on the network. When some of lines are removed it is more like some part of the network are supplied by only the distributed generation which can be seen as off-grid electrification. Table 1 shows the voltage profile, real and reactive power losses of online contingency analysis of the proposed network as suggested above.

More care must be taken in opening line 1-2 (from Afam to PH Z4) due to its large effect of almost large losses and also large voltage violations of 17 buses as shown in Figure 2. Another significant effect is opening line 2-6 (from PH Z2 to T1A) which has a voltage violation of 14 buses as shown in Figure 3 and losses very large to account for. Removal or opening of line 3-8 (from PH Z4 to T1A in zone 4) which can be considered as one of the off grid electrifications, where bus 8 is been fed from 10MW supply from gas turbine coming from Trans-Amadi which gave a voltage violations of 10 buses as shown in Table 1. Opening lines 1-3 (from Afam to PH Z4) and line 3-7 (from PH Z4 to T1B in zone 4) shows off-grid electrification where 25MW DG is supplying T1B and also where three DGs are supplying PH Z4. The total voltage violation for this scenario is 8 buses. All other line openings gave a voltage violations of 7 buses except opening line 4-14 (T2A Z2 to Trans-Amadi), line 6-15 (T1A Z2 to Aboloma), line 19-34 (from Onne Feeder to Refinery) and line 19-37 (Onne feeder to Daewoo Coy) which has a voltage violations of 6, and line 18-31 (from Akani to Rumuogba), line 18-32 (from Akani to Old Aba road) and line 19-33 (Onne feeder to NNPC) which has voltage violations of 5 buses as shown in Table 1. The best result which can be suggested further for off-grid electrification and the best network is the removal or opening of line 4-18 (from T2A Z2 to Akani) which has voltage violations of 4 buses as shown in figure 4. In this case it is suggested that Akani should be fed by 10MW gas turbine generation from Trans-Amadi and removed from the network. This scenario also gave the best real and reactive power losses as shown in Table 1.

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V CONCLUSION

Online contingency analysis is useful in designing a power system to ascertain the present and future effect of a Network. In the case of the Port Harcourt Network studied, it clearly shows more recommendations for the network as a result of cutting or removing some people from the network to be supplied by the Distributed Generation (off-grid electrification). Opening the line connecting from T2A (Z2) to Akani, this disconnects those fed by Akani, to only be fed by the 10MW gas turbine from Trans-Amadi, proffers the best network base on the minimal voltage violations and low real and reactive power losses. This is seen as off-grid electrification to those fed by Akani feeder. The study will aid in proper management of the Network in the presence of DGs and suggest other means to arrange the DGs for proper and effective use.

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