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The Effects of Distributed Generation in the Nigerian North East Zone

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KW–Kilowatts,
SVC–Static Var Capacitor

ABSTRACT

The effects of distributed generation in the Nigerian North East zone is discussed in this paper. DG capacity installation in the power system was modelled using NEPLAN software. Network loss reduction, reduction in transmission line losses and congestion as well as voltage profile improvement for the nodes of the network were some of the observed advantages in the results.

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Introduction

The unbundling of the Nigerian power market and accelerated technical progress has created opportunities for investors to invest in small generation capabilities with attendant reduction in the generation facilities size and unitary costs. Environmentally friendly renewable energy technologies and cleaner fossil fuel technologies are driving the demand for distributed energy generation. Users will be able to deliver energy on their own and to supply energy to the grid at low voltages. Energy reliability and security will be improved and losses recorded both in transmission and distribution networks will be minimised [1].

Distributed generation (DG) corresponds to small power production located close to the customer and connected to the distribution system. It can be implemented either by final customers, independent power producers (IPPs) or by distribution utilities. Final customers get an alternative supply for peak consumption or a backup option. IPPs have a business opportunity in the competitive electricity market and the utility see it as an interesting option to reduce losses, deal with voltage problems within the system, or to avoid or delay network expansion.

Benefits, such as the reduction of energy losses and energy not supplied (ENS) as well as improvement of voltages profiles have been mentioned in literature. Impact on the transmission network, due to a massive installation of DG, should be considered for proper network expansion and operation planning process.

Definitions

Growth of power markets and accelerated technical progress has led to reductions in the generation facilities size and unitary costs. This trend has led to new investments in generation with private participation. Environmentally friendly renewable energy technologies and cleaner fossil fuel technologies are driving the demand for distributed energy generation [2]. Distributed generation (also called embedded generation, on-site generation or decentralized generation) can be defined as the generation of small pockets of power located close to the customer and connected to the grid through the distribution system. However, different authors have proposed different definitions based on the facility sizes, storage abilities and generation capabilities. These can be summarized as:

- Electricity generation through small applications in relation to big central generation stations and connected to the power system through the distribution network. [4][5]
- DG is generation or storage of electricity in a micro scale and installed near to the load [12], with the option to exchange (sell or buy) with the power network. In some cases, maximum energy efficiency is achieved. [3]
- Electric power generation that corresponds to small units connected at distribution voltage and placed at the consumption point. [2][6][10][11]

These definitions are however, not exhaustive. The range of capacity used to consider an installation as DG varies widely, going from tens of kW to hundreds of MW depending on the total installed capacity of the power system.

Mathematical Concepts [1]

Evaluation of DG effects is made using the power flow over transmission lines and transformers.

A transmission network element is denoted in Figure 1 above with its initial and end nodes denoted by X and Y

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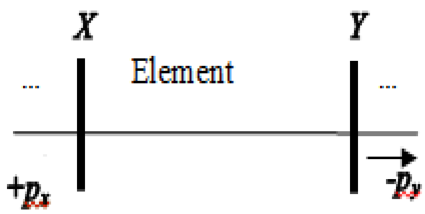

Figure 1. Power flow over a transmission network element.

respectively. Power flow over the element (x, y) from node X is denoted as $+p_x$ as power flows into the network through the node while power delivered from the network through node Y is denoted as $-p_y$. The difference in the sum of power received and power delivered is the power losses in the corresponding element [1].

$$E_{xy} = E_{yx} = p_x + p_y \quad (1)$$

Taking Z as the set of elements of a specific zone, the power losses of the zone are given by:

$$E_Z = \sum_{x \neq y \in Z} \alpha_{xy}$$

(2)

The power entering the element (x, y) through node x, p_x^+ and the power leaving the element (x, y) through node y, p_y^- are given by:

$$p_x^+ = \max(0, p_x)\,;\, p_y^- = \min(0, p_y)$$

(3)

For the set Z, the power entering the set P_x^+ and the power leaving the set P_y^- are given by:

$$P_Z^+ = \sum_{x \neq y \in Z} p_x^+ \,;\; P_Z^- = \sum_{y \neq x \in Z} p_y^-$$

(4)

The power transport, T, which is defined as the product of the sum of power received or delivered by the element (x, y) multiplied by its length l_{xy}, for the elements in set Z, is given by:

$$T_Z^+ = \sum_{x \neq y \in Z} p_x^+\, l_{xy};\; T_Z^- = -\sum_{y \neq x \in Z} p_x^-\, l_{yx}$$

(5)

Reduction in Line Losses and in the Use of Transmission Lines

Power transmission lines losses reduction of the set Z is evaluated with and without DG as given below:

$$\Delta E_Z = E_Z^0 - E_Z^{DG} \quad (6)$$

For a zone g, which comprises of the set Z and other sets, the reduction in the use of transmission lines is estimated through the micro-economic analysis of electricity transport activity [7] where the economic product of transport activity is given as a Cobb-Douglas function which is:

$$P_g * L = V * \phi * \sqrt{\left(\frac{M}{\rho}\right)} * \sqrt{E_g}$$

(7)

Where

P_g = Transmitted power for zone (g)
L = Transmission distance
V = Transmission voltage
Φ = Voltage phase angle
$(M/\rho)^{0.5}$ = Electrical conducting material
$(E_g)^{0.5}$ = Losses for the zone (g)

Therefore, from equation (5), electricity transport in set Z, T_Z, is the sum of the power delivered per element multiplied by the corresponding transmitted distance. From this, the percentage of avoided transport can be evaluated as:

$$\%T_Z = \frac{(T_Z^0 - T_Z^{DG})}{T_Z^0} * 100 \quad (8)$$

Economic Evaluation

Economic evaluation is done using the spot market price of electricity. Thus, the economic assessment of losses is obtained using the relation:

$$EAL = \frac{\sum_{i=1}^{g} \Delta E_i * mp}{IC^{DG}} \quad (9)$$

Where

EAL = Economic Assessment of Losses
ΔE_i = Avoided losses for g zone
mp = Spot market price of electricity
IC^{DG} = Installed DG capacity

The savings in transmitted power can be measured through the difference between the power transmitted with the use of DG and without the use of DG. This can be used to determine the reduction in the use of transmission lines.

For the set of elements in the set Z (from equation 4), the savings in transmitted power can be determined from the relation:

$$\Delta P_Z = P_Z^0 - P_Z^{DG}$$

(10)

Transmission Network and DG Modelling

The Nigerian North East zone is an import dependent zone as it does not have any power generating station [8], hence, the network elements were connected to the network at Damaturu node, to power the zone. Due to the very poor voltage regulation of the zone, a SVC was installed at Yola to boost node voltages in the zone.

Given its technical characteristics, DG is installed in medium voltage networks which correspond to 33kV voltage networks in Nigeria. The modelled capacities were installed as a reduction in active power in the nodes. Because the entrance of new capacity will necessitate a new generation despatch, this is avoided by subtracting the DG capacity to be installed from the existing conventional generation capacity. This adjustment is known as uniform allocation.

The choice of the node for the installation in the region was influenced by the node with the highest loss or poorest voltage regulation in the region. To this end, the DG was installed at Maiduguri.

The NEPLAN software was used to model the network elements and perform simulations. The load flow subroutine was used to obtain the results [9].

Result Analysis

Tables 1 and 2 show the results of the simulation of the network without DG and with DG respectively while the graphical representation of line losses for both the active and reactive power is depicted in figures 2 and 3 below.

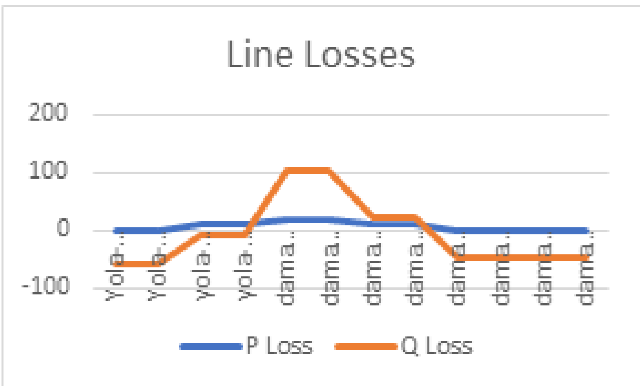

Figure 2.Line losses for the region

Table 1. Network losses and node profiles for the region.

	P Loss (MW)	Q Loss (MVar)	P Imp (MW)	Q Imp (MVar)	P Gen (MW)	Q Gen (MVar)	P Load (MW)	Q Load (MVar)	Qc Shunt (MVar)
Network	41.388	-34.777	1021.188	243.307	1021.188	243.307	979.8	453	174.916
Node Name	U (kV)	u (%)	Angle U (°)	P Load (MW)	Q Load (MVar)	P Gen (MW)	Q Gen (MVar)	Q Shunt (MVar)	
LC Jalingo	326.883	99.06	-33.3	69	40	0	0	0	
LC Gombe	311.537	94.41	-17.7	220.8	95	0	0	0	
LC Yola	330	100	-31.5	220.8	90	0	0	-174.916	
LC Damaturu	330	100	0	179.4	70	1021.188	243.307	0	
LC Maiduguri	272.394	82.54	-14.5	276	150	0	0	0	
LC Mambila	332.225	100.67	-0.2	13.8	8	0	0	0	

Table 2. Bus nodes with DG installation.

	P Loss (MW)	Q Loss (MVar)	P Imp (MW)	Q Imp (MVar)	P Gen (MW)	Q Gen (MVar)	P Load (MW)	Q Load (MVar)	Qc Shunt (MVar)
Network	38.479	-61.802	992.779	204.282	1018.279	216.282	979.8	453	174.916
Node Name	U (kV)	u (%)	Angle U (°)	P Load (MW)	Q Load (MVar)	P Gen (MW)	Q Gen (MVar)	Q Shunt (MVar)	
LC Jalingo	326.883	99.06	-33.3	69	40	0	0	0	
LC Gombe	311.537	94.41	-17.7	220.8	95	0	0	0	
LC Yola	330	100	-31.5	220.8	90	0	0	-174.916	
LC Damaturu	330	100	0	179.4	70	992.779	204.282	0	
LC Maiduguri	281.667	85.35	-12.8	276	150	25.5	12	0	
LC Mambila	332.225	100.67	-0.2	13.8	8	0	0	0	

From figure 2, it is observed that Damaturu-Gombe lines have the highest active power losses while Damaturu-Mambilla lines have the lowest active power losses.This can be attributed to the line loadings or line flows across the lines. The aggregate active power losses for the zone is 41.388MW which is 4.224% of the total load demand of the zone.

Maiduguri has the lowest bus voltage, which is rather too low and unsustainable. at the nominal value. All other buses have their voltages below nominal values.

Damaturu, the bus through which the network elements are connected, to get power for the zone, Yola and Mambilla are the only busses whose voltages are with the installation of a DG of 25.5MW capacity, which is 2.603% of the power demand of the zone, and connected to the network at Maiduguri, there was a redistribution of line flows. The line losses of Damaturu-Gombe lines remained unchanged but that of Damaturu-Maiduguri lines dropped by 31.12%. Also, the total aggregate network losses dropped by 7.56% to 38.479MW. Note that the losses reduced further with an increase in the output of the DG but the output was limited in standing with the definition of a DG as a small unit of power generation.

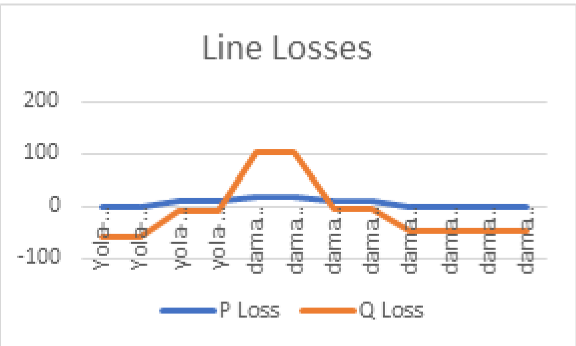

Figure 3. Line losses with DG installation.

The node voltages profiles improved by as much as 3.404% in some nodes but the node voltages of still tended towards the lower limit requiring reactive power compensation to bring them to nominal values.

References

[1] Camilo Tautiva, Hernando Duran and Angela Cadena “Technical and Economic Impacts of Distributed Generation on the Transmission Networks” IEEE 2011

[2] Lorrin Philipson and H. Lee Willis “Understanding Electric Utilities and De-Regulation” Taylor & Francis group. 2006

[3] SN Singh, Jacob Ostergaard and Naveen Jain “Distributed Generation in Power Systems: An Overview and Key Issues” www.orbit.dtu.dk/fedora/objects/orbit:59722/datastreams/file_5202512/content

[4] American Council for an Energy Efficient Economy “Distributed Generation” https://aceee.org/topics/distributed-generation. 2002-2016

[5] Cypress Creek “What Is Distributed Generation and How Might It Shape the Utility Industry’s Future?” https://ccrenew.com/news/what-is-distributed-generation-and-how-might-it-shape-the-utitlity-industrys-future. March 2016

[6] Thomas Ackerman, Goran Andersson, Lennart Soder “Distributed Generation: A Definition”. Science Direct Journal, 2001.

[7] A. Cadena, A. Marcucci, J. F. Pérez, H. Duran, H. Mutis, C. Tautiva, F. Palacios, “Efficiency analysis in electricity transmission utilities”. Journal of Industrial & Management Optimization, 2009,5(2):253-274. doi: 10.3934/jimo.2009.5.253

[8] Engr. Kingsley Osuoha “Daily Operational Report” www.nigeriasystemoperator.org May 2019.

[9] BCP Busarello + Cott + Partner Inc.; NEPLAN Users Guide V553, July 2011. http://www.neplan.ch/support_area/index.php

[10] Roger C. Dugan, Mark F. McGranaghan, Surya Santoso, H. Wayne Beaty “Electrical Power Systems Quality”. McGraw-Hill Companies. 2004.

[11] Eltaib Said Elmubarak, Ali Mohamed Ali "Distributed Generation: Definitions, Benefits, Technologies and Challenges". International Journal of Science and Research (IJSR), Volume 5 Issue 7. 2016.

[12] U.S. Department of Energy "The Potential Benefits of Distributed Generation and Rate Related Issues That May Impede Their Expansion: A Study Pursuant to Section 1817 of The Energy Policy Act of 2005". www.ferc.gov/legal/fed-sta/exp-study. 2007