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Contingency Analysis on 330kv Alaoji-Afam Power Network. Port Harcourt

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ABSTRACT: *Contingency Analysis on 330KV Alaoji-Afam power Network is necessary and compulsory in order to keep the power network operational at all times irrespective of failure on any element of the power system. the Alaoji-Afam 1 and 2 transmission network is a short line of 25km, The existing network of Aloji-Afam 1 and 2 power station generate at 10.5KV, with installed step-up/step-down transformer capacity of 162MVA (330KV/132KV/33KV) and 150MVA (330KV/132KV/33KV) respectively while the power rating was 130MW. The generator capacity is 60MW, the relay rating has 110volts (DC)-faint detector and 48volts (DC)-communicator. The breaker and the isolator accommodate current not above 500A. The Alaoji-Afam transmission network was being faced with the challenges of reactive power, active power, power factor, complex power. In determining the operating condition of 330kv Alaoji-Afam transmission network using line parameters, also to validate the difference between the pre-upgrade system and the post-upgrade system. Newton Raphson method was used in analysing fault current with line impedance of the network while Electric Transient Simulation software (ETAP) was used for the simulation, also Microsoft excel was used to justify the current percentage operation of the network. From simulation conducted, the excitation values were varied which enable the power network to regain its normal operating status, The result on Bus Voltage Operating indicate that all the Buses on the Pre-Upgrade were almost equal while the percentage operating of Bus 2, 1, and 33, was rated as the highest with approximate value of 98%, the least percentage operating was approximated to 94% in Bus 35 and 34. The result on the rated voltage indicates that all the rated voltage was 330KV on all the Buses. The operating voltage on Bus 2 (129.214) was the highest while Bus 33 and 34 (123.314) was the lowest respectively. The percentage operating on all the Buses was approximated to 40% on the Post-Upgrade of Alaoji-Afam 1 and 2 Transmission Network. The result between the percentage operating of the Pre-Upgrade System and percentage operating of the Post-Upgrade System shows that 330KV was the rated voltage while the different between percentage operating of the Pre-Upgrade System was higher than the percentage operating of the Post-Upgrade System forAlaoji-Afam 1 and 2 Transmission Network, which cause the Alaoji-Afam 1and 2 transmission network operating without achieving the desired results.*

KEYWORDS: *Active power, Contingency Analysis, Complex power, Power factor, Pre-Upgrade and Post-Upgrade System, Reactive Power.*

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I. INTRODUCTION

The condition of Nigeria power system has reached a stage for demand of state of emergency in respect of electricity supply; the Nations modern development of transmission network is classically wide and difficult engineering system whose vigorous existence is essential to industrial and socio-economic. The various efforts made to rescue the short falls in the power sector has not yielded the expected result. The challenge of Reactive power is mutually the power system network voltage control solution. Importantly, a stability of reactive power be obtained in the operation of a power system because control of voltage can be lost if this is not accomplished. [9], Voltage instability contributes to a large extent the system collapse or blackouts. It is a major concern for today’s electric power system operators, the Nigerian National grid experiences on an average of thirty-five (35) system collapses every year over the past ten (10) years.

According to [10], control network is measured to work at consistently when the working parameters are expected steady with the end goal of investigation. Underneath this situation, the crest to-crest adequacy of the network current is accepted occasion invariant (steady). At the point when the aggravation is viewed as extensive, the dependability concern is alluded to as 'transient strength', which is the capacity of the power network to keep up synchronism when exposed to serious transient unsettling influence. The subsequent network reaction to such aggravation includes vast trips of generator rotor edge which is affected by the non-straight power-point connection [11]. Power network security shows how verified the power network typical state or with anticipated possibilities. Some real records survey of the protection of a power structure is the transient solidness [3]. In transient dependability appraisal, the basic or critical clearing time (CCT) is a significant parameter in surveying the strength of intensity, which is the most extreme permissible time term that an issue may happen in power network previous to losing synchronism, the shortcoming or fault clearing time (FCT) is set indiscriminately in a power network, thus, if the FCT is more than CCT, the network losses synchronism [15]. A strong power network is to a great extent controlled by its reaction to aggravations; in this manner, a high estimation of CCT shows a hearty power network [13].
The Nigerian 330kV grid network is faced with series of challenges like voltage instability, elongated transmission network, nature of transmission lines, high power loss [6], combined with consistent influence request increment and absence of delicate hardware to identify and settle the difficulties [7]. Due to inadequate transmission system, the system could be easily stressed, such that a relatively small disturbance can lead to total blackout or voltage breakdown [14]. The function of the power system network is to generate and transmit power to load centres at specified voltage and frequency levels and statutory limits exist for the variation about base levels. The nominal frequency shall be 50Hz ± 0.5%. Under system stress the frequency on the power system could experience variations within the limits of 50Hz ± 2.5% (i.e. 48.75 – 51.25 Hz and the nominal voltage shall be 330kv, 132kv, 33kv, 11kV ± 0.5% while Under system stress or following system faults, voltages can be expected to deviate outside the limits by a further ± 5% (excluding transient and sub-transient disturbances) [9]. [17], a three-dimensional finite element model of a transmission tower-line system is created based on a real project. Using theoretical analysis and numerical simulation, incremental dynamic analysis of the power transmission tower-line system is conducted to investigate the effect of strain rate on the nonlinear responses of the transmission tower and line. The selected tower for the analysis which has a height of 60.5m and a square base area of 10.16m × 10.16m at ground level. The angle steel with equal section is used for all tower members. Main members of the tower are made of Q345, and secondary members are made of Q235 [16].
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Contingency analysis of power network is necessary and compulsory in order to develop means of maintaining and keeping the power network operational at all times irrespective of failure on any elements of the system. These elements of the power system include its electrical equipment (e.g. transformers, generators, transmission lines, circuit breakers, towers, gas lines, relay and bus bars etc), the power system security is very vital, also outages experienced has caused draw back to the growth of local industries, end users (consumers) and the economy of the country

1.3 Aim of the Study
This study is aimed at conducting contingency analysis on the 330KV Alaoji-Afam transmission network.

1.4 Objectives of Study
Demand on 330kv power network increased constantly and caused the over loading of the network. Therefore, the objective of this research work was to

i. Collect data on transformers and transmission lines, in 330KV Alaoji-Afam power network.
ii. Use line parameters to verify the operating state of the 330kv Alaoji-Afam power Network.
iii. Use Newton-Raphson method for the power flow equation while Electrical transient analyzer tool (E-tap) and Microsoft Excel was used in order to investigate the system responses before during and after the system disturbance.
iv. Validate the investigation between the existing system and the improved compensation system.

1.5 The Research Scope
The scope of this research is to carry out contingency analysis on 330KV Alaoji-Afam power network in the south-south Nigeria.

II. LITERATURE REVIEW

The origin of the Nigeria electric power transmission network can be traced back to the year 1898, the 132KV network was constructed in 1962 between Lagos and Ibadan, with a small generating plant [18], he did a work on "Simulation Modelling of Voltage Stability of an Interconnected Electric Power Network" and he considered voltage stability of an interconnected power network but the generators of the interconnected electric power network was not considered while in this work the generators and the Transmission lines of 330kv Alaoji-Afam power network were simulated. The National grid was first constructed in 1968, of which the kainji hydro station supplies power via a 330KV, primarily the transmission network has three members' 132KV subsystem in the Western, Northern and Eastern parts of the country while 330KV and 132KV system was run by "Nigeria Dams Authority (NDA)", and "Electricity Corporation of Nigeria (ECN)" respectively. The 330KV Network was coordinated from kainji power supply control room, and the 132KV power Network operated by the load dispatchers located at Ijora Power Supply Lagos. In 1972 NDA and ECN was merged together and we have National Electric Power Authority (NEPA), thus ushering in centralized regulation and coordination of the entire rapidly growing 330KV and 132KV National network. These networks are characterized by different instability which causes power failure. [19] who did a work on "Load flow evaluation of the Nigeria 330kv Power System" he measured the location of the generating station and how it affects transmission but the generators of the interconnected electric power network was not considered while in this work the generators and the Transmission lines of 330kv Alaoji-Afam power network were simulated.

The Nigeria lattice network consists of a small number of generating stations like many other developing countries and is situated bmainly in isolated areas close to the raw materials required for generation. Currently, the Nigeria Electricity Network comprises of 11,000KM Transmission lines (330 and 132KV), 24,000KM of sub-transmission lines (33KV), 19,000KM of distribution lines (11KV) and 22,500 substations [20], he did a work on "Distance Relay Protection Improvement of Alaoji- Afam 330kV Transmission Line", and He presented insight on the protection system of Alaoji-Afam 330kV Transmission Line but The entire Alaoji-Afam 330KV was not simulated while in this work both the generating and transmission lines were simulated Alaoji-Afam 330KV was simulated. figure 2.1 below, shows the Nigeria 330kV system comprise of eleven (11) creating stations containing three (3) hydro and eight (8) warm, twenty one (21) load stations and thirty six (36) transmission lines with an all out introduced limit of 6500MW. The warm creating stations are mostly situated in the Southern piece of the nation like Okpai, Afam, Sapele, Delta (Ughelli), Egbin, Olorunshogo and Omotosho, while the hydro producing stations are found predominantly in the Middle Belt/Northern piece of the nation like Kainji, Shiroro and Jebba. The Nigeria 330-kV lattice system can be assembled into three (3) areas: North, South-east and South-west segments.

The Northern and South-west are associated through one twofold circuit between Jebba TS and Oshogbo. The South-East is associated with the South-West through a solitary line from Osogbo to Benin and afterward one twofold circuit line from Ikeja West to Benin. The line chart and information of the Nigerian 330kV lattice organize were sourced from the National Control Center (NCC) of the PHCN, Oshogbo, Nigeria [21].

III. MATERIALS AND METHODS

Materials in Alaoji-Afam 1 and 2Transmission Lines

The Alaoji-Afam 1 and 2, consist of 2 (60MW)generators, with transformer rating of 162MVA, 330KV/132KV/33KV and 150MVA, 330KV/132KV/33KV while the length of the transmission line was 25KM From Alaoji to Afam, Port Harcourt, Nigeria. The transmission data was collected from Transmission Company of Nigeria (TCN) for the purpose of investigating and analysing of the voltage magnitude (v) and phase angle (s), active power (p), reactive power (Q), and power losses, as a requirement for contingency analysis. Newton-Ranpson method is use in analysing fault current and line impedance of the network while Electric Transient Simulation software (ETAP) is in conducting load flow analysis using Newton-Ranpson method power flow equation.

Network Description

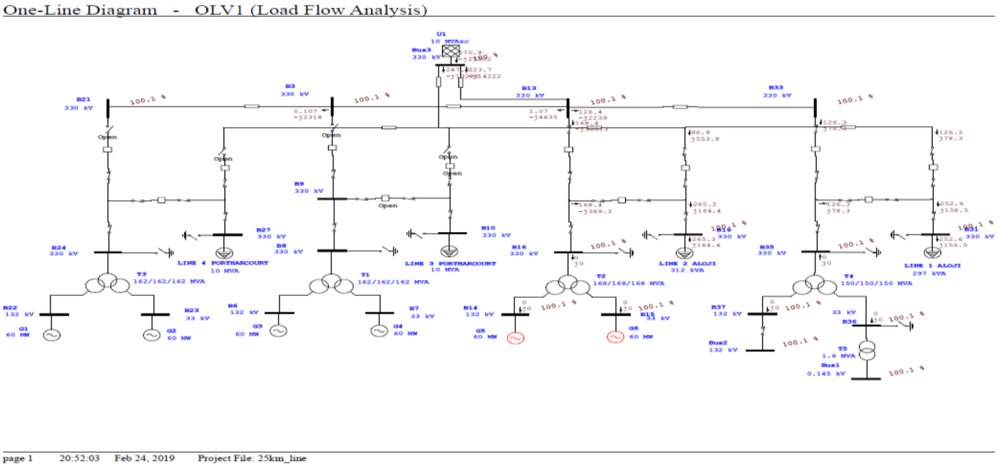

Figure 3.1: The Pre Upgrade of Alaoji-Afam 1 and 2 Network Diagram

Calculation of Load Current in Alaoji-Afam 1 and 2, Transmission Network

Power Triangle is use in analyzing the reactive power, apparent power and power factor.

Transformer load in SVA= $\sqrt{3}\,IV$ 3.1

Active power in watts or kW= $\sqrt{3}\,IV\ \cos\theta$ 3.2

Reactive power in VAR or kVAR= $\sqrt{3}VI\sin\theta$ 3.3

Apparent power in VA or kVA= $\sqrt{\mathrm{kW}^2+\mathrm{kVAR}^2}$ 3.4

Power factor, $\cos\theta = \frac{\text{Active power}}{\text{Apparent power}} = \frac{\text{kW}}{\text{kVA}}$ 3.5

Complex power, S = P + jQ 3.6

Current $I = \frac{P(KVA)}{\sqrt{3}\,IV}$ 3.7

Phase voltage $= \frac{\text{line voltage}}{\sqrt{3}}$ 3.8

Where, I, represent Current; V, represent Voltage and $\cos\theta$ represent the power factor at primary and secondary of Transformers respectively.

Table 3.1 the Transformer Current Rating and Phase Voltage in the Primary and Secondary Transformer in Alaoji-Afam 1 and 2 Transmission Network.

Base Transformer Rating	Transformer Rating Current	Current Connected in Delta/Star	Phase Voltage
162MVA and 330KV/132KV/33KV transformer	Primary Load current I_p	283.4A	191KV
	Secondary load current I_s	708.6A	762KV
	Secondary load current I_s	2834A	19.1KV
150MVA and 330KV/132KV/33KV	Primary Load current I_p	262.4A	191KV
	Secondary load current I_s	656.1A	762KV
	Secondary load current I_s	2624A	19.1KV

Transmission Line Parameters in 160MVA and 150MVA Transformer in Alaoji-Afam 1 and 2

$R_o = \frac{\rho\times\ell}{A}\ \Omega/\text{km}$ 3.9

$X_o = 0.1445 log_{10}\frac{D_{GMD}}{r} + \frac{0.0157}{n}\Omega/\text{km}$ 3.10

$GMD = \sqrt[3]{D_{aa}\times D_{ab}\times D_{ac}} = 1.26D$ 3.11

$r = \sqrt{\frac{A}{\pi}}$ 3.12

$Z_o = R_o + jX_o$ 3.13

$Y_o = G_o + jB_o$ 3.14

Alaoji-Afam 1 and 2, Transmission Line Performance

$\%\,efficiency = \frac{power\ \ delivered\ \ at\ the\ receiving\ -end}{power\ \ sent\ from\ the\ sending\ -end}\times 100$ 3.15

$$B = \frac{7.5}{\log_{10}\left(\frac{D_{GMD}}{r}\right)} \times 10^{-6} \quad 3.16$$

$$Y_o = G_o + jB_o \quad 3.19$$

$$\%\ \text{voltage regulation} = \frac{V_s - V_r}{V_r} \times 100 \quad 3.17$$

V_s - Sending-end voltage
V_r - Receiving-end voltage

$$voltage\ drop\ (V_d) = \frac{\sqrt{3}\times(R\cos\emptyset + \times\sin\emptyset)}{number\ \ of\ conductor\ \ /phase\ \times 100} \times lenght\ of\ line\ section \quad 3.18$$

V_d - Voltage drop (V)
I_L - Load current (Amp)
R - The resistance of the conductor (Ohms)
X - The reactance of the conductor

Newton-Ranpson Method

In numerical analysis, Newton's method (also known as the Newton-Ranpson method), named after Isaac Newton and Joseph Raphson, is a method for finding successively better approximations to the roots (or zeroes) of a real-valued function. The Newton-Ranpson method in one variable is implemented as follows:

Given a function f defined over the real x, and its derivative f', we begin with a first guess $x0$ for a root of the function f. Provided the function satisfies all the assumptions made in the derivation of the formula, a better approximation $x1$ is

$$x_1 = x_0 - \frac{f(x_0)}{f'(x_0)} \quad 3.19$$

$$x_{n+1} = x_0 - \frac{f(x_0)}{f'(x_0)} \quad 3.20$$

$$f_1(X_1, \cdots, X_n) = n_1 \quad 3.21$$

$$f_2(X_1, \cdots, X_n) = n_1 \quad 3.22$$

$$\vdots$$

$$f_n(X_1, \cdots, X_n) = n_n \quad 3.23$$

$$\begin{aligned} X_1^* &= x_1^{(0)} + \Delta x_1^{(0)} \\ X_2^* &= x_2^{(0)} + \Delta x_2^{(0)} \\ &\vdots \\ X_n^* &= x_n^{(0)} + \Delta x_n^{(0)} \end{aligned} \quad 3.24$$

$$g_k(x_1^*, \cdots, x_1^*) = g_k(x_1^*, \cdots, x_1^*) + \Delta x_1^{(0)} \frac{\partial g_k}{\partial x_2}\Big|^{(0)} + + \Delta x_2^{(0)} \frac{\partial g_k}{\partial x_2}\Big|^{(0)} + \cdots + + \Delta x_n^{(0)} \frac{\partial g_k}{\partial x_n}\Big|^{(0)} \quad 3.25$$

$$\begin{bmatrix} dy_1/dx_1 & dy_1/dx_2 & \cdots & dy_1/dx_n \\ dy_2/dx_1 & dy_2/dx_2 & \cdots & dy_2/dx_n \\ \vdots & \vdots & \ddots & \vdots \\ dy_n/dx_1 & dy_n/dx_2 & & dy_n/dx_n \end{bmatrix} \begin{bmatrix} \Delta x_n^{(0)} \\ \Delta x_n^{(0)} \\ \vdots \\ \Delta x_n^{(0)} \end{bmatrix} = \begin{bmatrix} 0 - g_1(x_1^{(0)}, \cdots, x_n^{(0)}) \\ 0 - g_2(x_1^{(0)}, \cdots, x_n^{(0)}) \\ \vdots \qquad \vdots \\ 0 - g_n(x_1^{(0)}, \cdots, x_n^{(0)}) \end{bmatrix} \quad 3.26$$

IV. RESULTS AND DISCUSSION

Table 4.1: The Active Power (kW), Reactive Power (kVAR), Apparent Power (kVA), Frequency (Hz), Power factor Cos Ø, Complex power S, Transformer %Loading and Current (I) in Alaoji-Afarm line 1and 2

S/NO	Alaoji-Afarm line 1and 2	Active Power (kW)	Reactive Power (kVAR)	Apparent Power (kVA)	Frequency (Hz)	Power factor Cos Ø	Complex power S	Transformer %Loading	Current (I)
1	Alaoji-Afarm line 1	4527	3395	5659	50	0.8	$4527 + j3395$	44%	99
2	Alaoji-Afarm line 2	4755	3567	5944	50	0.8	$4755 + j3567$	18%	104

The Alaoji-Afarm 1 and 2, Transmission Line and voltage drop Performance

Table 4.2 Alaoji-Afarm 1 and 2, Transmission Line Performance

S/NO	Alaoji-Afarm Transmission Line	Line Efficiency	% voltage regulation	Voltage drop (V)
1	Alaoji-Afarm line 1	98%	44%	0.35
2	Alaoji-Afarm line 2	100%	42%	0.35

The Post-Upgrade of Alaoji-Afarm 1 and 2 Transmission Network

Electric Transient Simulation software (ETAP) result of the synchronous generator (G5 and G6) connected to the post-upgrade of Alaoji-Afarm 1 and 2 which were excited indicate that the system has recovered as shown in Figure 4.4 below.

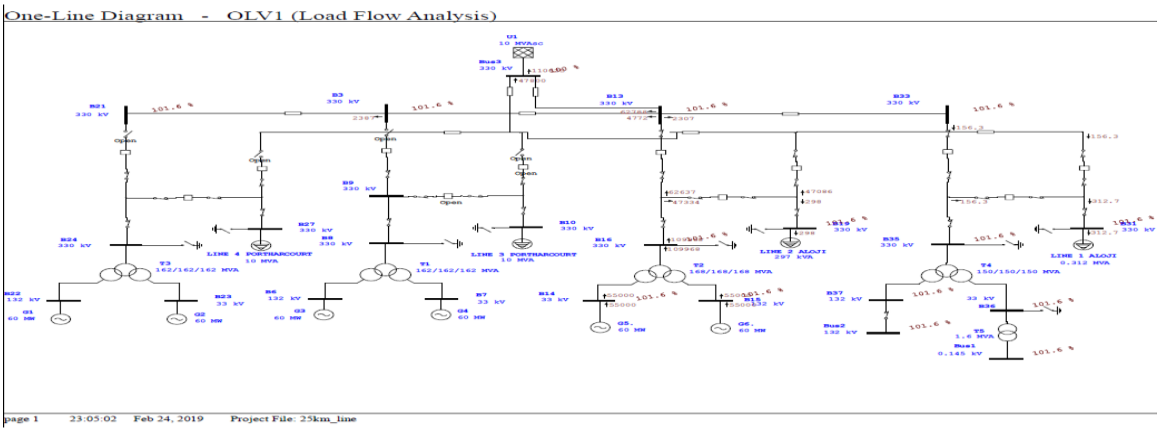

Figure 4.4: Post-Upgrade of Alaoji-Afarm 1 and 2 Transmission Network

The results of Synchronous generator (G5 and G6) of the post-upgrade connected to Alaoji-Afarm 1 and 2 transmission network were carried out on Electric Transient Simulation software (ETAP) is used in reducing equivalent network with different parameters of excitation system which indicate that the system is able to recover from a 3-phase fault near Alaoji-Afarm 1 and 2 on the 400 kV line and is quite adequate when the main gain is set to 400KA and the maximum values for upper and lower field voltage limits in the normal (Positive field current) condition as shown in Figure 4.5. and 4.6 below.

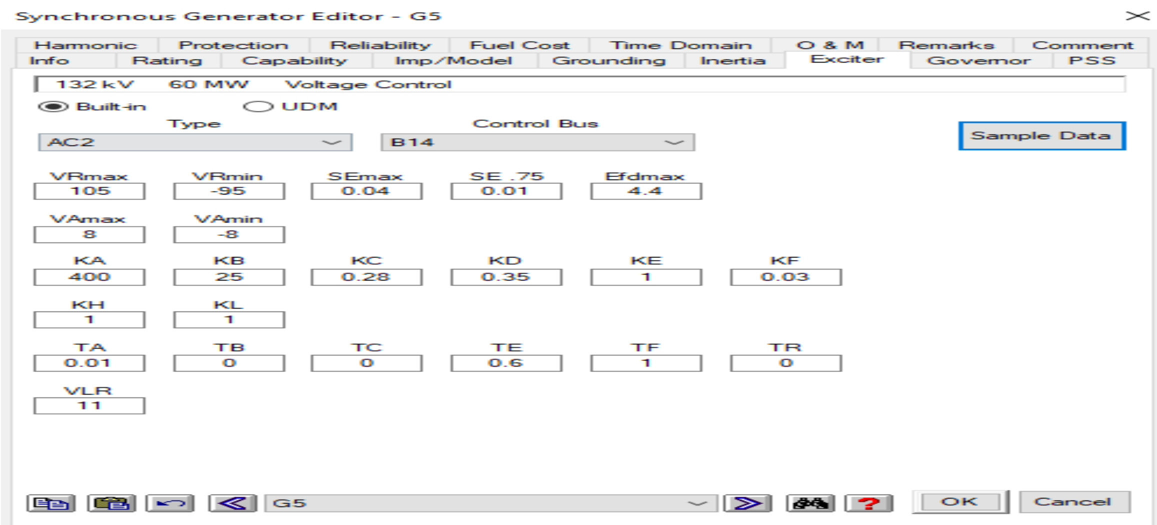

Figure 4.5: Post-Upgrade G6 Exciter of Alaoji-Afarm 1 and 2 Transmission Network

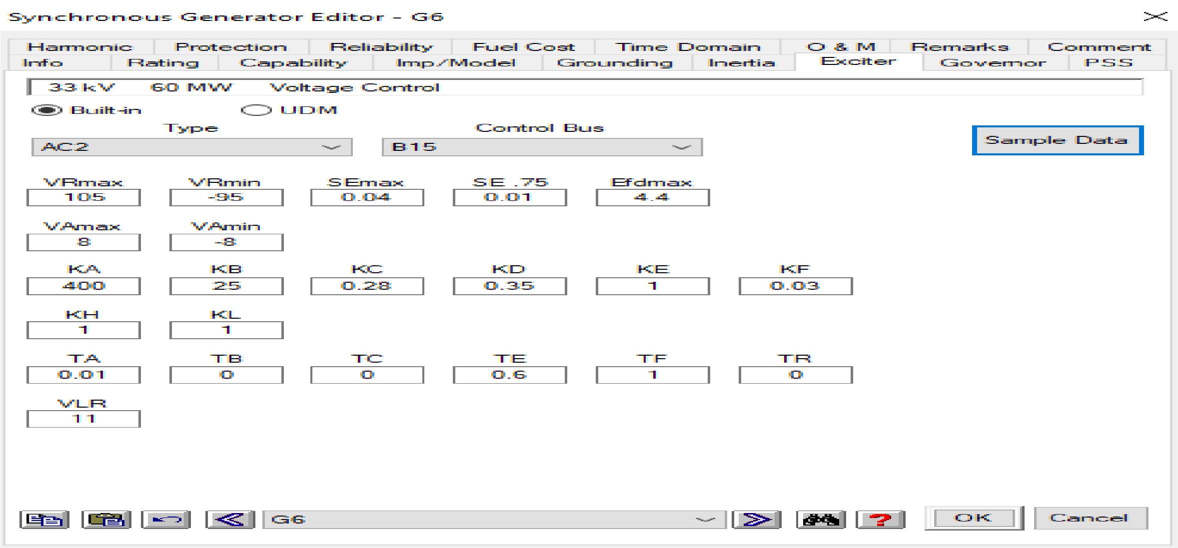

Figure 4.6: Post-Upgrade G6 Exciter of Alaoji-Afarm 1 and 2 Transmission Network

Table 4.3 Bus Voltage Operating Condition for the Pre-Upgrade of Alaoji-Afarm 1 and 2 Transmission Network

S/NO.	Bus Numbers	Rated Voltage (KV)	Operating Voltage (KV)	% Operating
1	Bus 2	330	322	97.5758
2	Bus 1	330	323	97.8788
3	Bus 37	330	312	94.5455
4	Bus 36	330	313	94.8485
5	Bus 35	330	311	94.2424
6	Bus 34	330	310	93.9394
7	Bus 33	330	323	97.8788
8	Bus 32	330	321	97.2727

Table 4.4: Bus Voltage Operating Condition for the Post-Upgrade of Alaoji-Afarm 1 and 2 Transmission Network

S/NO.	Bus Numbers	RATED VOLTAGE (KV)	OPERATING VOLTAGE (KV)	% OPERATING
1	Bus 2	330	129.214	39.15575758
2	Bus 1	330	128.222	38.85515152
3	Bus 37	330	124.323	37.67363636
4	Bus 36	330	125.113	37.9130303
5	Bus 35	330	124.213	37.64030303
6	Bus 34	330	123.314	37.36787879
7	Bus 33	330	123.314	37.36787879
8	Bus 32	330	128.131	38.82757576

Table 4.5 Bus Voltage Operating Condition for the Pre-Upgrade and Post-Upgrade of Alaoji-Afarm 1 and 2 Transmission Network.

S/NO.	Bus Numbers	Rated Voltage (KV)	% OPERATING of the Pre-Upgrade System	% OPERATING of the Post-Upgrade System
1	Bus 2	330	97.5758	39.1557576
2	Bus 1	330	97.8788	38.8551515
3	Bus 37	330	94.5455	37.6736364
4	Bus 36	330	94.8485	37.9130303
5	Bus 35	330	94.2424	37.640303
6	Bus 34	330	93.9394	37.3678788
7	Bus 33	330	97.8788	37.3678788
8	Bus 32	330	97.2727	38.8275758

Charts Representing Various Tables

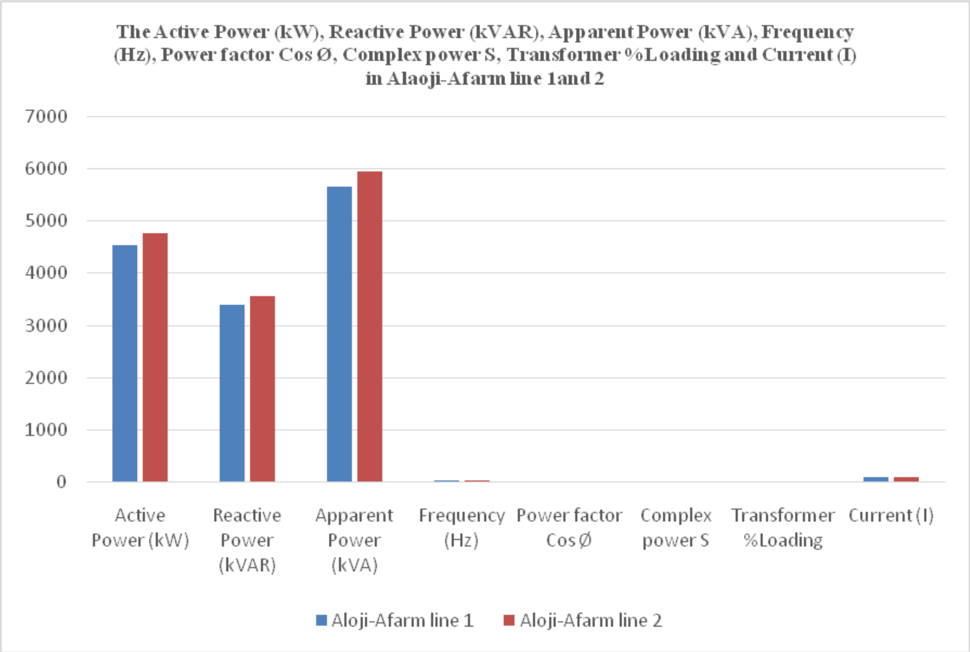

Figure 4.2 The Active Power (kW), Reactive Power (kVAR), Apparent Power (kVA), Frequency (Hz), Power factor Cos Ø, Complex power S, Transformer %Loading and Current (I) in Alaoji-Afarm line 1and 2

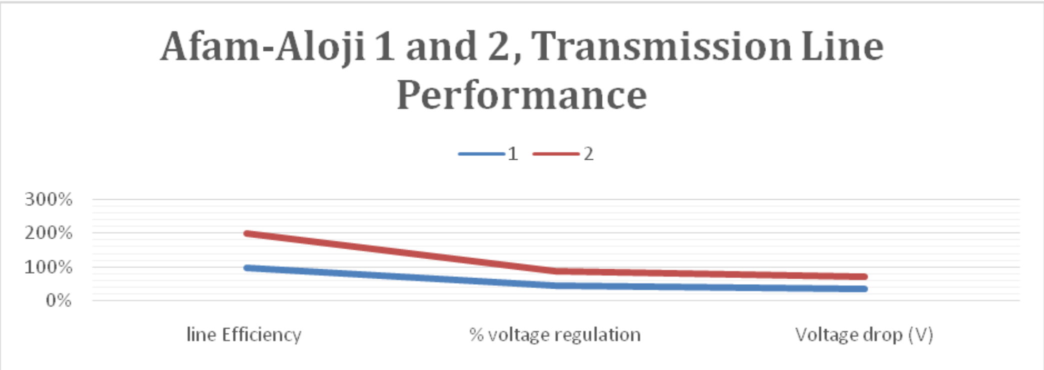

Figure 4.3 The Line Efficiency, Percentage Voltage Regulation and The Voltage Drop Performance in Alaoji-Afarm 1 And 2 Networks.

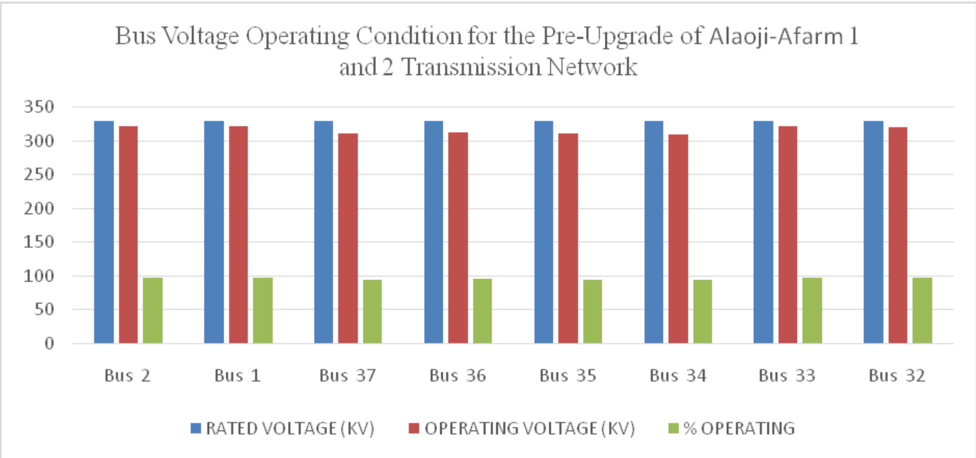

Figure 4.7: Bus Voltage Operating Condition for the Pre-Upgrade of Alaoji-Afarm 1 and 2 Transmission Network

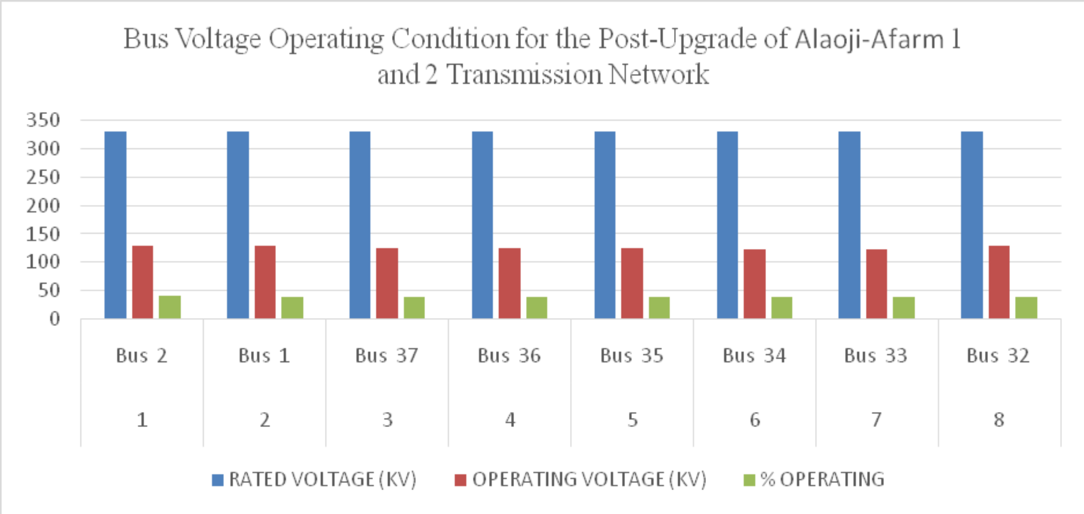

Figure 4.8: Bus Voltage Operating Condition for the Post-Upgrade of Alaoji-Afarm 1 and 2 Transmission Network

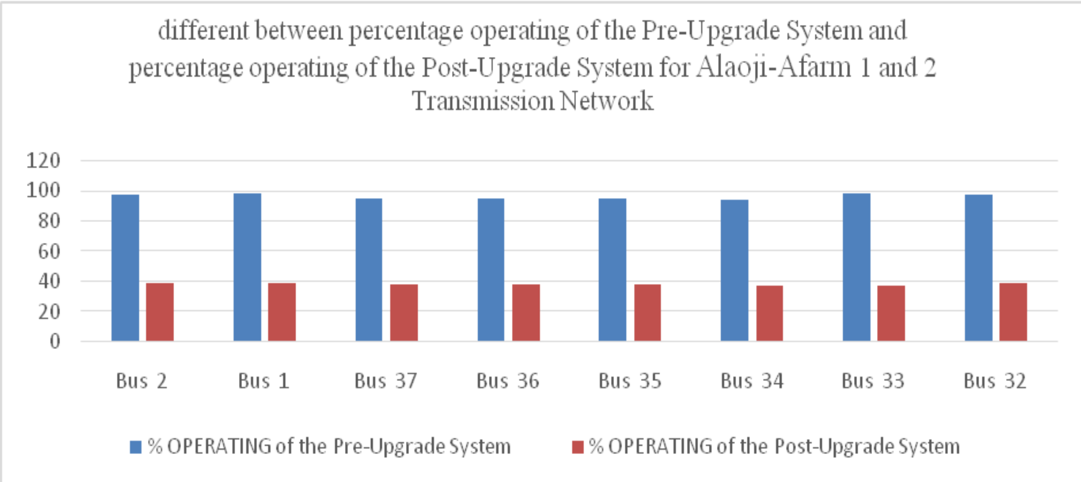

Figure 4.8: Different between Percentage Operating of the Pre-Upgrade System and Percentage Operating of the Post-Upgrade System for Afam-Aloji1 And 2 Transmission Network.

V. CONCLUSION AND RECOMMENDATIONS

Conclusion

From the simulation conducted using Electrical Transient Analyzer, the following problems were associated with the transmission lines and the generators; The transmission network is faced with the challenges of reactive power, active power, power factor, complex power, etc., generator 5 and 6 were under-excited (both generators are not operational), the generating station and the transmission lines are not maximized, and the bus operating condition of the existing power network is very high.

Hence, the result for line efficiency performance in Alaoji-Afarm 1 and 2 was determined as (98% and 100%) respectively. The regulation of the line change in the receiving end voltage which is expressed as the full load, keeping the sending end voltage and frequency constant. The limiting factor of voltage regulation is considered in deciding the size of either conductor or type of insulation. However, the voltage regulation, regulate and maintain a forced voltage under different load condition. Importantly, current need to be lowered in order to keep the voltage drop within acceptable values of $(\pm 5 - \pm 6\% \; or \; 0.95Pu - 1.05Pu)$.

Electric Transient Simulation software (ETAP) result on load flow analysis reduces equivalent network with different parameters of excitation, the network condition as described clearly indicate that the system is able to recover following a 3-phase fault near Alaoji-Afarm 1 and 2 on the 330 kV line and is quite adequate when the main gain is set to 400KA and the maximum values for upper and lower field voltage limits in the normal (Positive field current) condition are used. The result between the percentage operating of the Pre-Upgrade System and percentage operating of the Post-Upgrade System in table 4.5 shows that 330KV was the rated voltage while the different between percentages operating of the Pre-Upgrade System was higher than the percentage operating of the Post-Upgrade System for Alaoji-Afarm 1 and 2 Transmission Network.

Recommendations

To ensure optimum performance and reliability of electricity in 330KV transmission network of Alaoji-Afarm 1 and 2,Port Harcourt, Nigeria, the following recommendations are suggested based on the findings,

1. To stop load shading at Alaoji-Afarm 1 and 2, Port Harcourt, Transmission Company of Nigeria (TCN) in Nigeria, should enable Alaoji-Afarm 5 and 6 to be active for optimal transmission of bulk power to Port Harcourt distribution network of Nigeria.
2. The Transmission Company of Nigeria (TCN), should create another transmission station for optimal distribution of electricity in Rivers State.
3. For stable transmission of power in south-south Nigeria, particularly Port Harcourt to be achieved, the grid system should be decentralized.
4. The Federal and State governments should build new generation and transmission facilities in each state of the federation, as this will reduce the distance power is being transmitted.

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