International Journal of Electrical and Electronics Engineering Studies
Vol.6, No.1, pp. 13-26, 2020
Published by **ECRTD-UK**
ISSN 2056-581X (Print), ISSN 2056-5828(Online)

ANALYSIS OF HARMONICS OF 132/33 KV IN BENIN CITY, NIGERIA USING COMPENSATION TECHNIQUE

[1]Dr. Eyenubo, Ogheneakpobo Jonathan,
[2]Dr. Okpare Anthony Onoharigho.
[3]Ebisine, Ezekiel Ebimene.
[1,2,3]*Department of Electrical/Electronic Engineering, Delta State University, Oleh Campus, Nigeria.*

ABSTRACT: *The work is focused on the analysis of harmonic in four number power transformers of 132/33 kV which are 3 x 60MVA and 1 x 30 MVA; instrument used to measure the parametric data of harmonic current is power harmonic analyzer Owon' (HDS1021M) Handheld Digital Storage Scope. The simulation was performed using three-phase programmable voltage source transformer over load tap changer (OLTC). The load variation used for the simulation of transformers in these eight substations feeders. The results obtained showed comparison before compensation the values of kW, % PF and % loading and that after compensation showed that the compensation technique used for the analysis of these transformers showed great improvement.*
KEY WORDS: power transformers; compensation; simulation; over load tap changer; electric transient analyzer program

INTRODUCTION

Power quality is a set of electrical boundaries that allows electrical equipment to function in its intended manner without significant loss of performance or life expectancy. This suggests that the required electrical devices needed in anticipation of energy cannot be substituted in key areas of economy such as industries, agriculture, transportation and service sector; thus, with growth of residents in an area, standard of living and rapid industrialization of energy being generated is expected to grow [1-2]. Only few industries in Nigeria have huge foreign exchange outflows associated for generator importations, the huge cost of running these generators have brought significant negative social, economic and environmental impacts on the economy. Harmonics are majorly generated by nonlinear loads which are increasing both in number of units and their ratings. Unlike linear loads which have constant impedance and a current wave shape that mirrors the applied voltage, nonlinear loads do not present constant impedance to the circuit The nonlinear loads characteristics associated with power electronic loads causes harmonic currents that could result in the frequency distortion which interface with communication systems and misoperation of control [3-4].

Perchance, the best formulation of power quality is, 'the supply of voltages and system composed of the user of electric power that utilizes electrical energy from the distribution arrangement without cessation [5-6]. Distribution line network of harmonic analysis is an important discourse in electric power systems since the increased use of outfits are sensitive to harmonics this has increased the number of undesirable harmonic-related conditions. The power quality challenges and the means of keeping them under control calls for concern. [7]

International Journal of Electrical and Electronics Engineering Studies
Vol.6, No.1, pp. 13-26, 2020
Published by **ECRTD-UK**
ISSN 2056-581X (Print), ISSN 2056-5828(Online)

Modern power installations are not void of nonlinear loads that are responsible for presence of harmonic contents like the case under study of distribution transformers serves feeder substations where customer substation transformers. It could be more worrisome where customers generate significant harmonic waveform distortion that have effect on other utility customers. Since consumers or end users can be considered as harmonic producers to some degrees, utilities may find it is difficult to pinpoint the right location of the harmonic source, particularly when resonant networks come into play. As a first measure of mitigating harmonics, utilities are to ensure that before distributing power to end user, it is pertinent they put some control measures on how to control harmonics be carried out as a remedial measure before thinking other means of addressing the harmonics generated from end users [8].

RESEARCH METHODOLOGY

The study presents an investigation of the effects and mitigation of harmonics in distribution systems, it involves the following: carrying out literature review of the effects of harmonics in electrical power supply systems. Data collected for the harmonic measurement from four number of transformers 132/33 kV of 3 x 60 MVA and 1 x 30 MVA. The instrument used to measure the parametric data of harmonic current is power harmonic analyzer Owon' (HDS1021M) Handheld Digital Storage Scope. The simulation was performed on the distorted waveform and spectrum under case study [9].

Analysis of Data and Simulation

The Electric Transient Analyzer Program software allows for the building and to customize harmonics frequency spectrum with unimproved case sources for 0 – 2500 Hz the number of buses where bus 1 is having 132 kV nominal while buses 2-5 are 33 kV; and store on the library's shelves. Any complex waveform can be composed of a sinusoidal component at the fundamental frequency and a number of harmonic components which are integral multiplies of the fundamental frequency. The instantaneous value of voltage for non-sinusoidal waveform or complex wave can be expressed as [10]

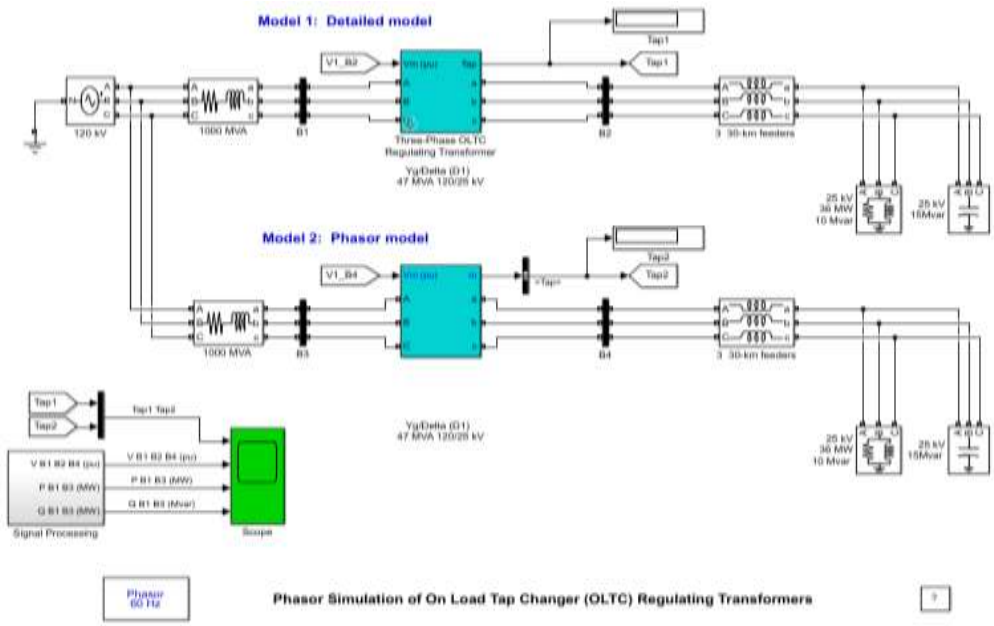

Figure 1: Simulink model for reducing harmonics on distribution transformer using simplex optimization technique.

Three-Phase Programmable Voltage Source transformer is used to vary the 33 kV system voltage within Buses 2-5 in order to observe the over load tap changer (OLTC) performance; the transformer simulation which has featured that is either a continuous or discrete results in wave shapes used to observe variations of phasor voltages and currents. When the device was used, the gain in simulation speed provided by the phasor model of the transformer was replaced by a duplicate of the phasor model. At the start of simulation, the transformer resulting voltage at Bus 2-5 was at 1.011 p.u. Then if time t = 5 s, the source internal voltage will suddenly be lowered to 0.85 p. u, so that the 33 kV voltages drop to 0.986 p. u, which is within the permitted voltage range. By reversing the switch included in the OLTC allows reversal connections of the regulation winding so that it is connected either addition or subtraction. Voltage regulation can be done by amending the transformer turns ratio; this can be obtained by connecting on each phase, a tapped winding can be in series with each $120/\sqrt{3}$ kV winding and this leverage for better compensation.

International Journal of Electrical and Electronics Engineering Studies
Vol.6, No.1, pp. 13-26, 2020
Published by **ECRTD-UK**
ISSN 2056-581X (Print), ISSN 2056-5828(Online)

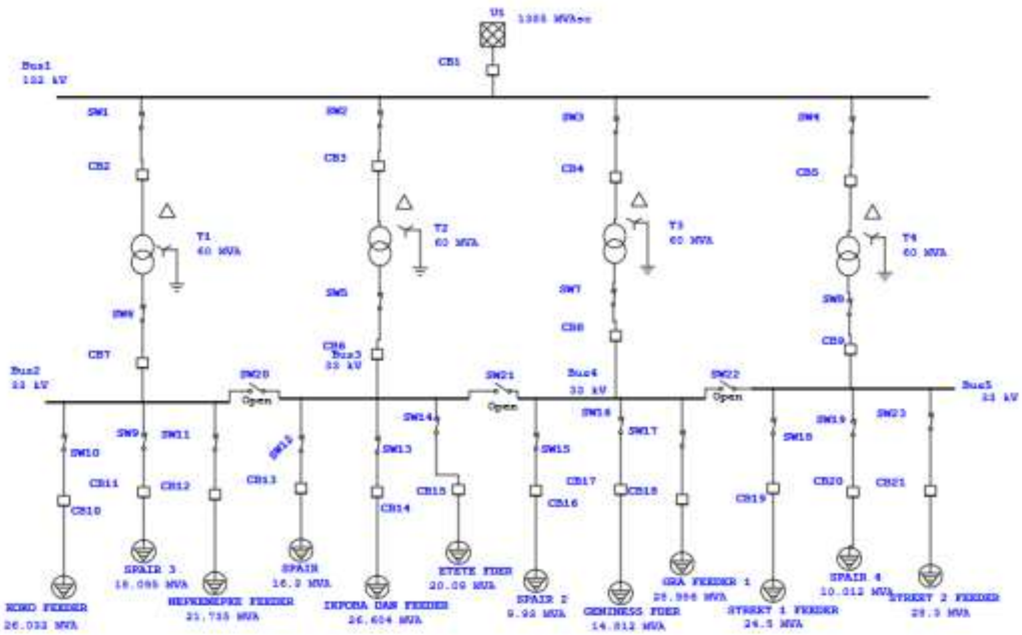

Figure 2: Single line Load Flow Diagram without Compensation

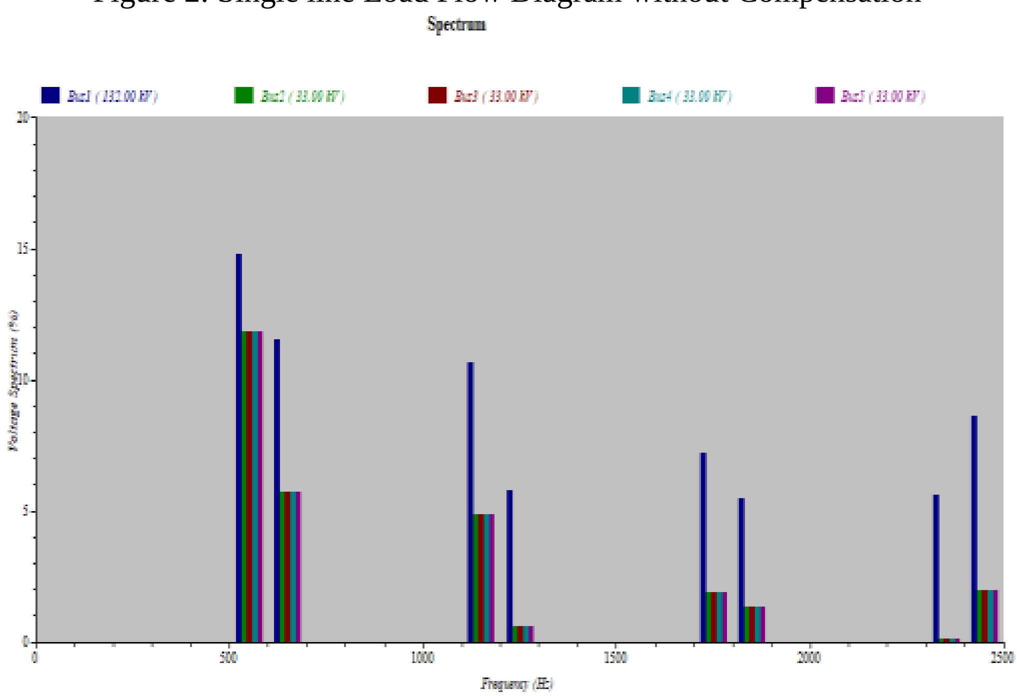

Figure 3: Harmonic spectrum with Unimproved Case

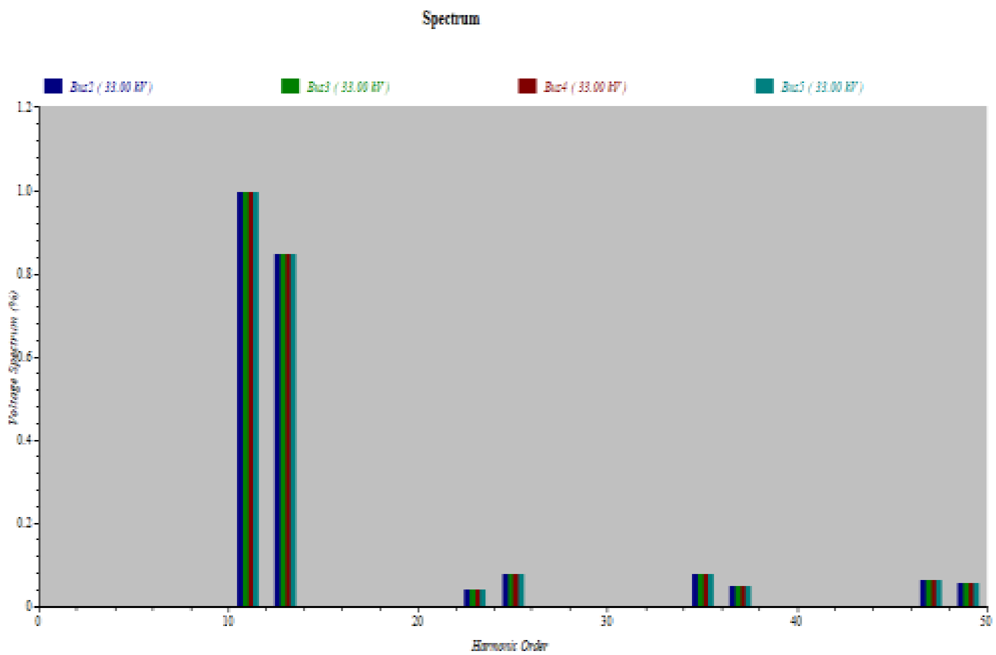

Figure 4: Harmonic spectrum with Improved Case

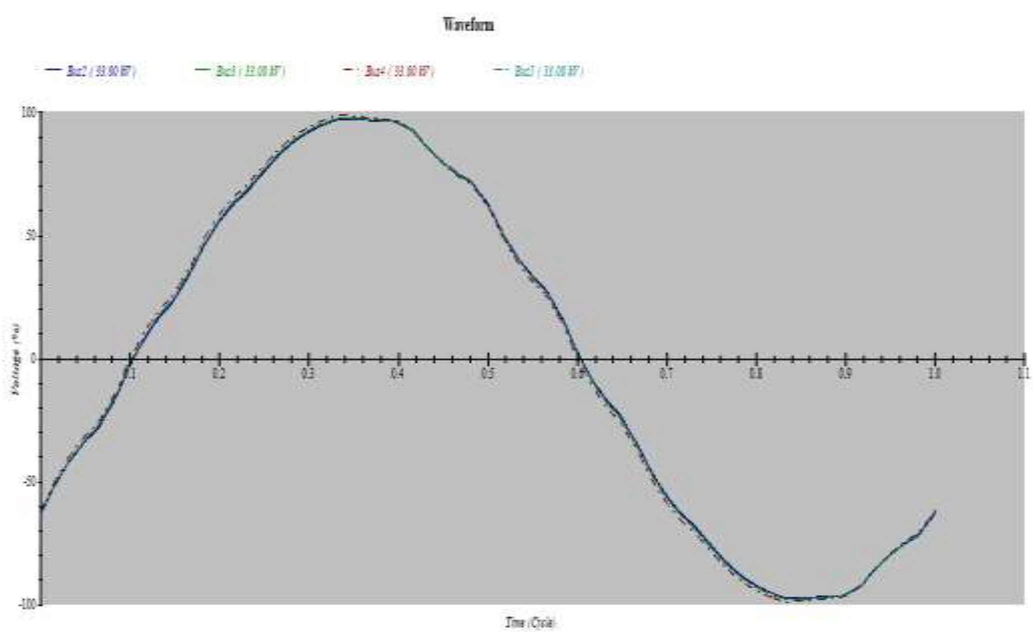

Figure 5: Waveform with Harmonics

International Journal of Electrical and Electronics Engineering Studies
Vol.6, No.1, pp. 13-26, 2020
Published by **ECRTD-UK**
ISSN 2056-581X (Print), ISSN 2056-5828(Online)

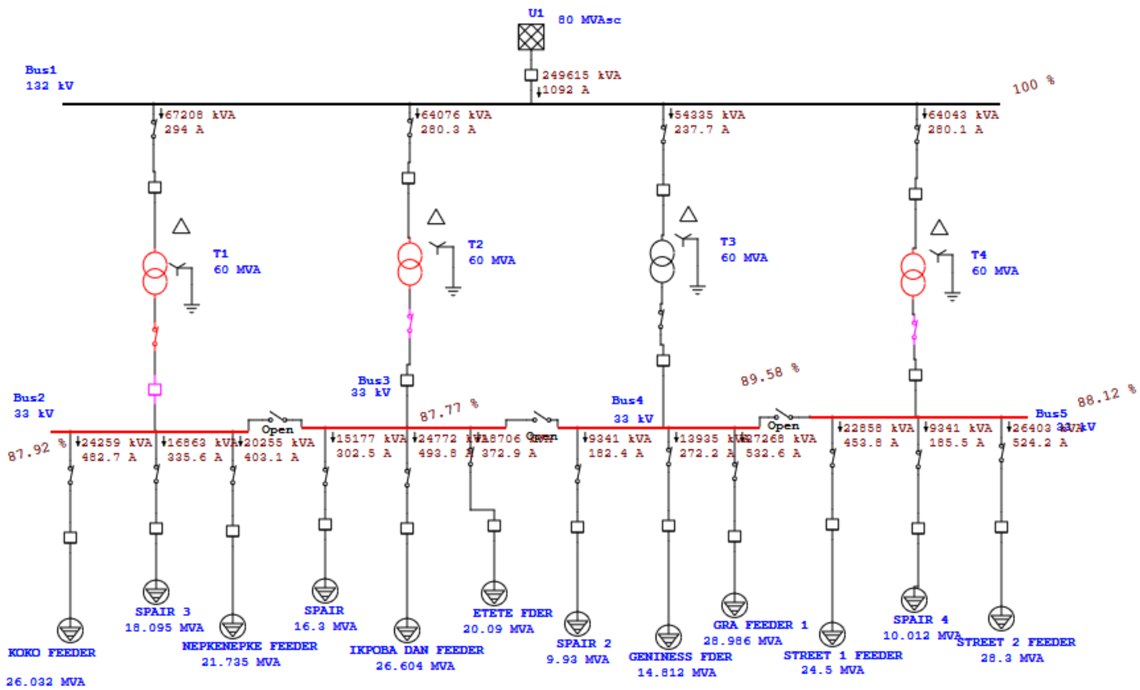

Figure 7: Single line Load Flow Diagram with Open Isolator

Table 1: ID Branch Parameter of Cable and Transformers

ID	From Bus	Allowable	kW Flow	kvar Flow	Amp Flow	% PF	% Loading	% Voltage Drop	kW Losses	kvar Losses
Cable1	Bus3	342.5 A	0	-42670	758.3	0	221.4	-0.05	21.06	19.67
Cable4	Bus4	342.5 A	0	-39538	702.7	0	205.1	-0.04	18.08	16.89
Cable5	Bus5	213.2 A	0	-41650.3	739.5	0	346.8	-0.14	150.3	61.55
Cable6	Bus2	342.5 A	0	-41682.1	740	0	216	-0.15	68.19	63.67
T1	Bus1	60000 kVA	54043.8	-13660	991.1	-96.95	92.9	1.6	163.8	7369.4
T2	Bus1	60000 kVA	54043.8	-13660	991.1	-96.95	92.9	1.6	163.8	7369.4
T3	Bus1	60000 kVA	54043.8	-13660	991.1	-96.95	92.9	1.6	163.8	7369.4
T4	Bus1	60000 kVA	54043.8	-13660	991.1	-96.95	92.9	1.6	163.8	7369.4

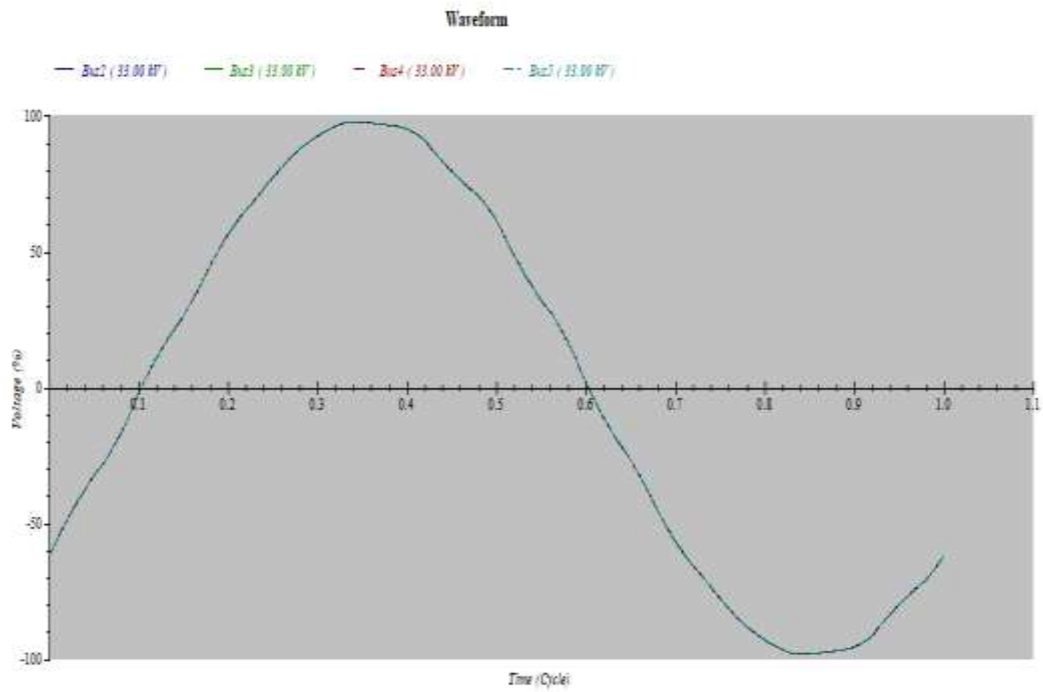

Figure 6: Waveform without Harmonics

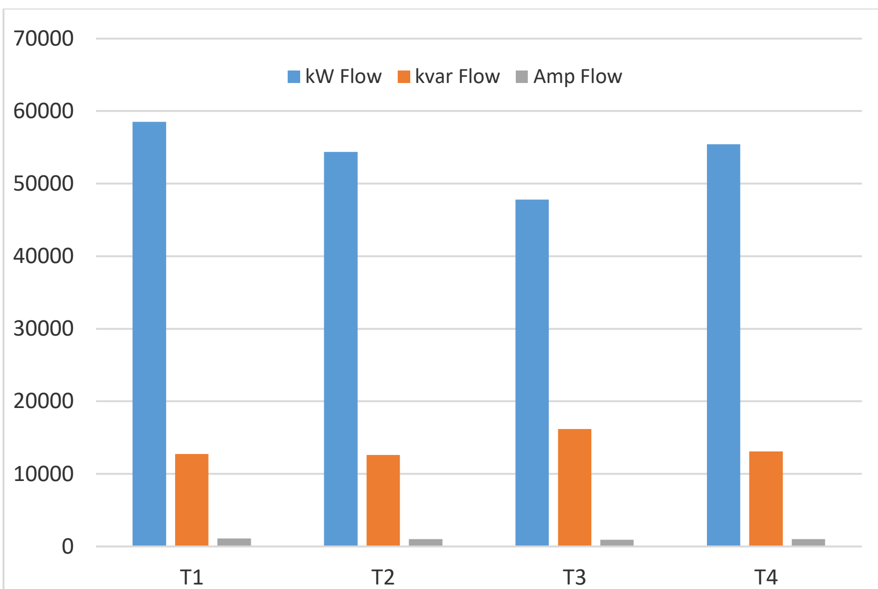

Figure 8: T1-T4 vs. kW flow, kvar flow and Amp flow

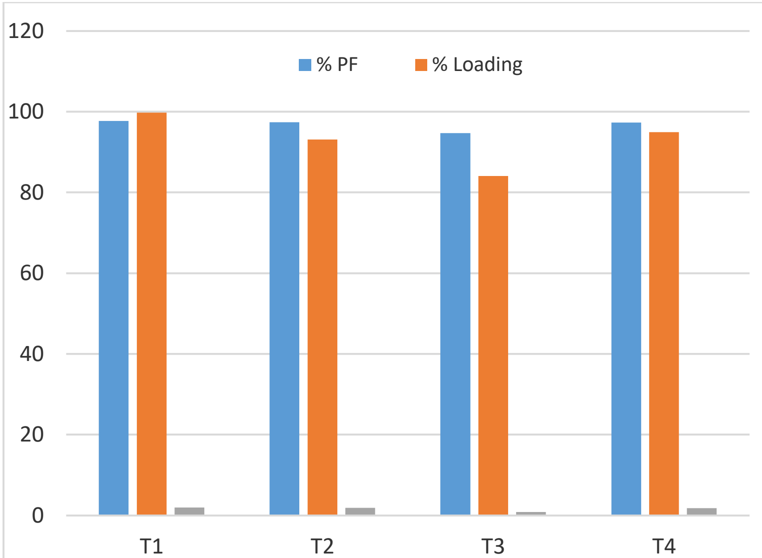

Figure 9: T1-T4 vs. % PF, % Loading and % Voltage Drop

Figure 10: T1-T4 vs. kW losses and kvar losses

Table 2: Load flow without compensation

Average values before compensation:13672.5 kW, the kvar 5989.2, the Amp rating 244.3, the % PF 72.17 and % loading is 69.01;

ID FEEDER	Rating/Limit (kvar)	Rated kV	kW	kvar	Amp	% PF	% Loading
CAP 1	-40800	33	0	-40168.8	601.1	0	93.4
CAP 2	-44029	33	0	-42449.2	526.2	0	92.4
CAP 3	-42890	33	0	-41495.2	628.2	0	91.5
CAP 4	-42918	33	0	-41362.8	546.4	0	90.5
ETETE	20090	33	12351.2	6021.1	241.6	79.43	77.1
GUINNESS	14812.5	33	11351.4	5065.4	251.2	73.64	68.3
GRA	28986.2	33	21840.3	10260.5	316.5	69.21	65.2
IKPOBA DAM	26604	33	20212.5	12171.1	348.1	70.13	68.5
KOKO	26032	33	21403.7	10161.1	247.3	72.21	66.4
NEKPENEKPE	21735	33	16351.4	6210.4	261.2	74.35	71.1
SPAIR 1	16300	33	11317.2	5406.3	214.1	73.43	69.6
SPAIR 2	9929.8	33	6503.4	2431.4	142.4	70.54	67.3
SPAIR 3	18095	33	14014.3	5134.1	207.4	71.55	66.4
SPAIR 4	10012	33	6551.4	2101.3	144.3	69.45	69.2
STREET 1	24500	33	10131.6	10121.2	211.6	70.51	70.7
STREET 2	28300	33	12041.2	10263.5	345.5	71.63	68.3

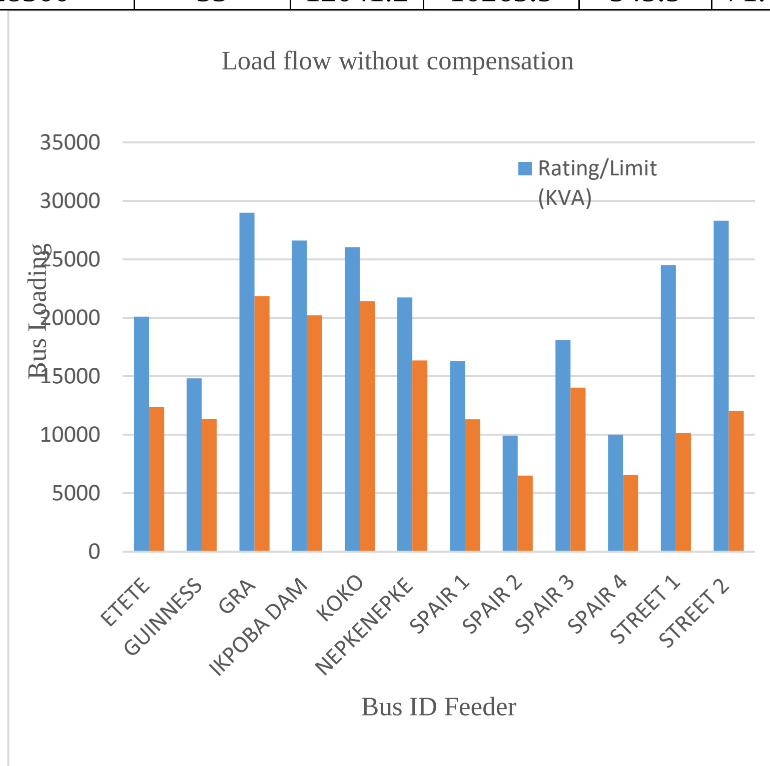

Figure 11: 33 kV Load flow without compensation

International Journal of Electrical and Electronics Engineering Studies
Vol.6, No.1, pp. 13-26, 2020
Published by **ECRTD-UK**
ISSN 2056-581X (Print), ISSN 2056-5828(Online)

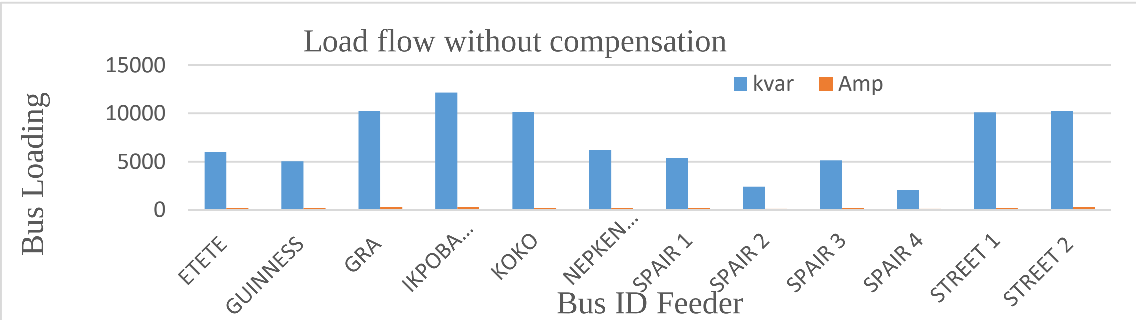

Figure 12: 33 kV Load flow without compensation

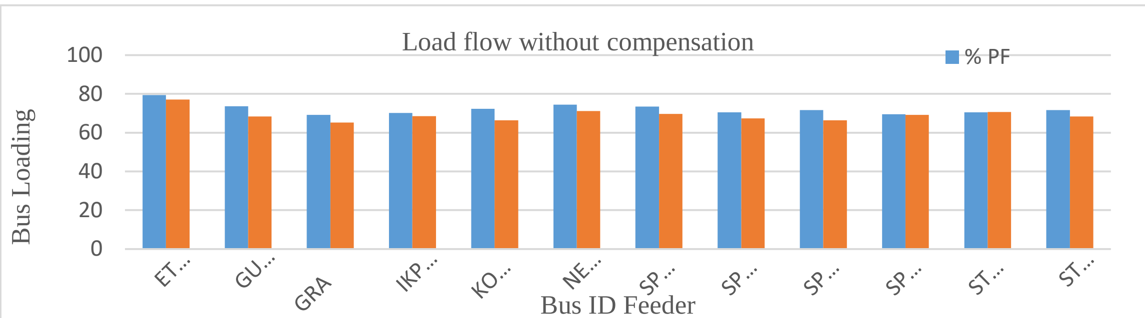

Figure 13: 33 kV Load flow without compensation

Table 3: Load Flow with Compensation

ID FEEDER	Rating/Limit (kvar)	Rated kV	kW	kvar	Amp	% PF	% Loading
CAP 1	-40800	33	0	-39538	702.7	0	99.2
CAP 2	-44029	33	0	-42670	758.3	0	98.2
CAP 3	-42890	33	0	-41650.3	739.5	0	98.4
CAP 4	-42918	33	0	-41682.1	740	0	98.2
ETETE	20090	33	18614.7	7032	354.2	93.55	96.5
GUINNESS	14812.5	33	12936.4	7032.4	260.9	87.76	95.1
GRA	28986.2	33	26071.8	12339.3	510.5	90.39	93.1
IKPOBA DAM	26604	33	22188	14214.2	469.2	84.2	97.6
KOKO	26032	33	22666	12290.9	459.9	87.91	95.5
NEKPENEKPE	21735	33	19629	8840.5	384.2	91.18	92.2
SPAIR 1	16300	33	13650.2	8621.2	287.8	84.55	90.4
SPAIR 2	9929.8	33	8756.9	4577.5	175.9	88.62	89.2
SPAIR 3	18095	33	16284	7486.6	319.9	90.86	90.4
SPAIR 4	10012	33	8884.3	4405.4	177.8	89.59	92.2
STREET 1	24500	33	21266.2	11688.3	431.5	87.64	94.3
STREET 2	28300	33	25192.8	12289.2	499.4	89.88	96.1

Average values before compensation:18011.7 kW, 9234.8 kvar, 360.9 Amp, % PF 88.84 and % Loading 93.55

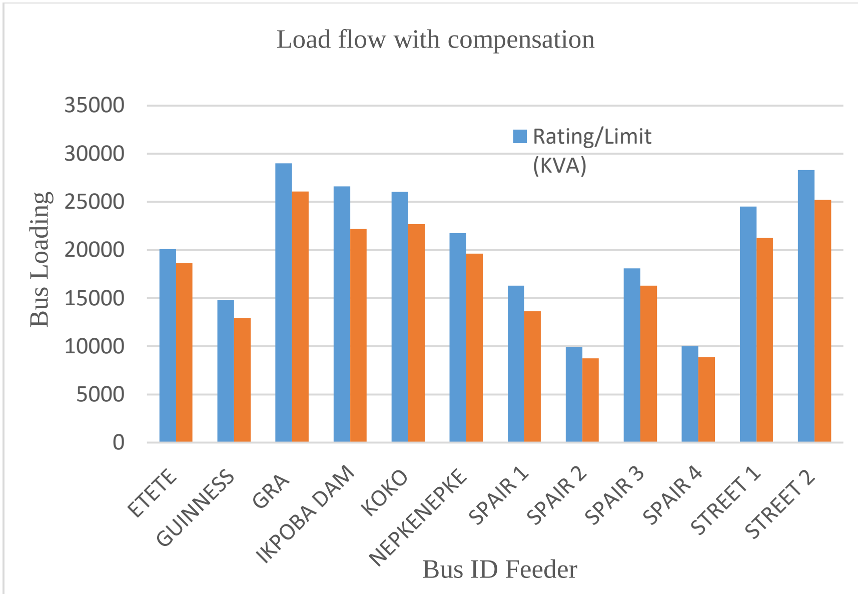

Figure 14: 33 kV Load flow with compensation

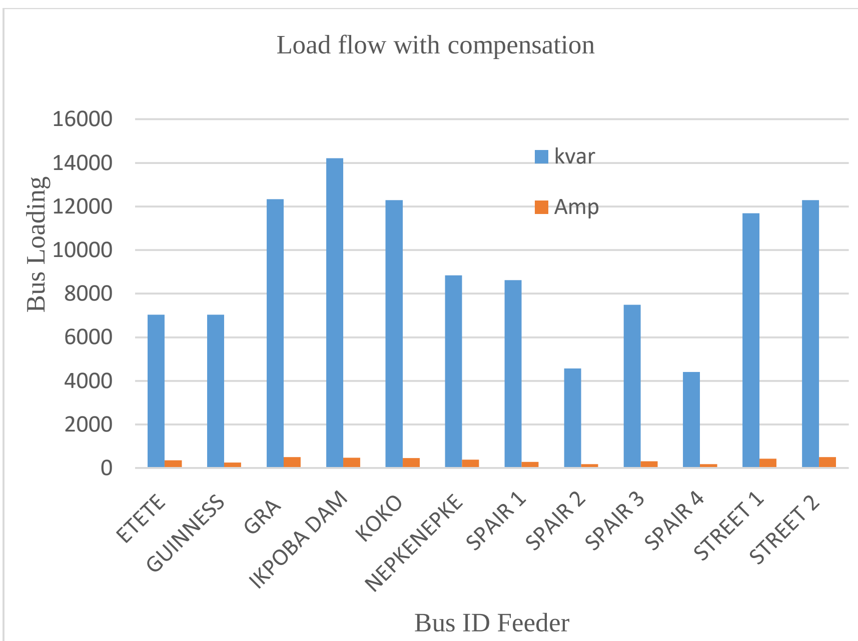

Figure 15: 33 kV Load flow with compensation

International Journal of Electrical and Electronics Engineering Studies
Vol.6, No.1, pp. 13-26, 2020
Published by **ECRTD-UK**
ISSN 2056-581X (Print), ISSN 2056-5828(Online)

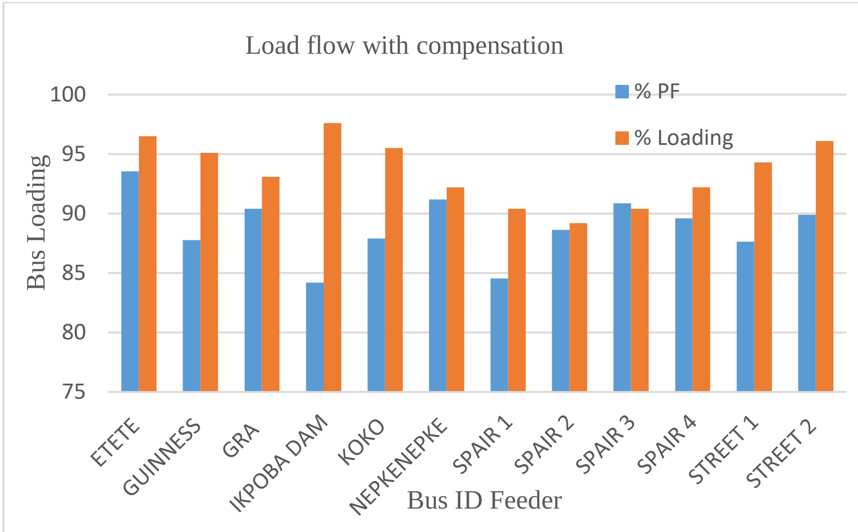

Figure 16: 33 kV Load flow with compensation

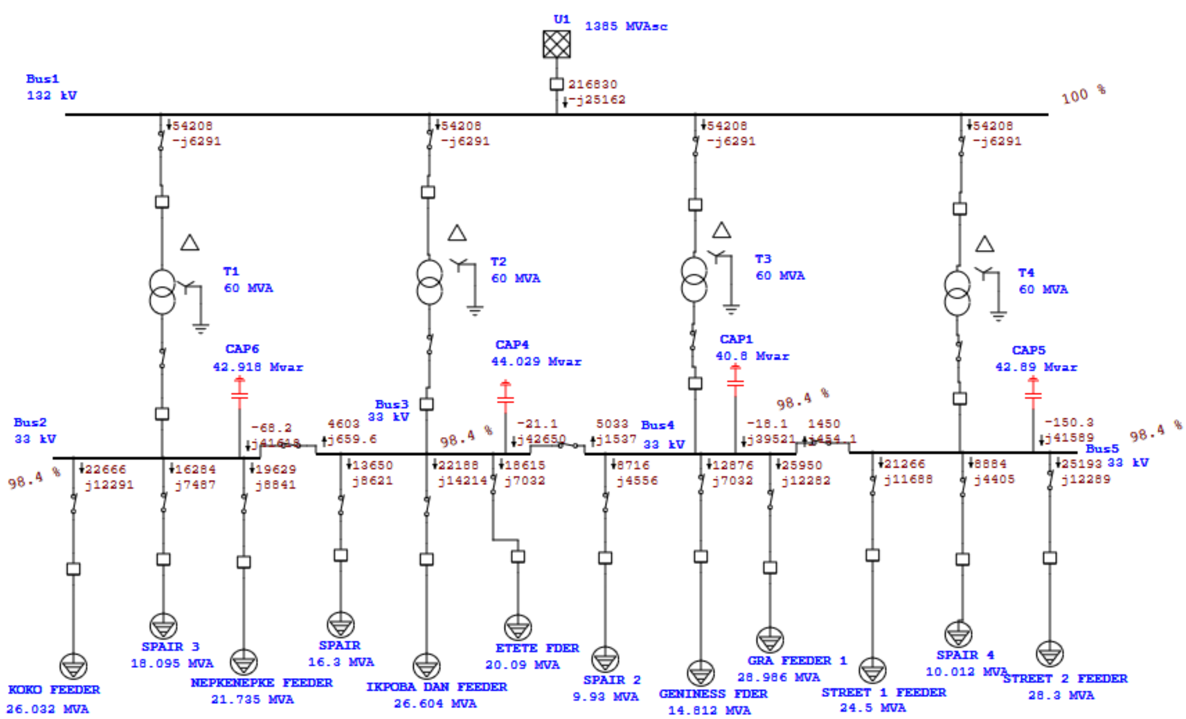

Figure 17: Single line Load Flow Diagram without Compensation

RESULT AND DISCUSSION

Figure 3 shows frequency spectrum from 0-2500 Hz, buses 2-5, at bus 2 shows the highest, while buses 4 and 5 the spectra are low in a non-compensation condition. This also applies to Figure 4; but Figure 5 is the waveform with some harmonic contents. But in Figure 6 is the waveform after compensation has been applied, which is free from harmonics.

From Figure 2, shows the load flow diagram with the Isolator in an open condition from the ETAP analysis. Table 1 shows the ID Branch Parameter of Cable and Transformers bus parameter indicating the number of buses where bus 1 is 132 kV nominal while buses 2-5 are 33 kV. The loading parameter are as indicated in the table same applies for kW flow, kvar flow, ampere flow, % PF, % loading, % voltage drop then the kW and kvar losses.

From Table 1: gives rise to plots in Figure 8 which is the plot for T1-T4 versus kW flow, kvar flow and Amp flow, Figure 9 shows the plot % PF, % loading and % voltage drop versus T1-T4, while Figure 10 shows the plot of T1-T4 versus kW losses and kvar losses.

From Table 2 is the state without compensation applied, thus Figure 11 is the plot of ID feeders versus the Rating/Limit (kvar) and kW, Figure 12 is the plot of the ID feeders and the kvar and Amp, while Figure 13 is the ID feeder plot versus %PF and % loading.

From Table 3 is the state with compensation applied, thus Figure 14 is the plot of ID feeders versus the Rating/Limit (kvar) and kW, Figure 15 is the plot of the ID feeders and the kvar and Amp, while Figure 16 is the ID feeder plot versus %PF and % loading.

CONCLUSION

The simulation performed using three-phase programmable voltage source transformer with over load tap changer (OLTC) the load variation used for the simulation on transformers in these eight substations feeders, it is obvious from the result before compensation the values of kW, % PF and % loading as 13672.5, 72.17, 69.01; while after compensation the values are 18011.7, 88.84, 93.55 that with compensation on the four transformer. Thus, the losses noticed before compensation can be accounted for if compensation is carried out on these transformers.

References

[1]. IEC 61000-4-30 77A/356/CDV, 2001, '*Power Quality Measurement Methods'*
[2]. Oseni, M.O. (2011). An analysis of the power sector performance in Nigeria. *Renewable and Sustainable Energy Reviews*, *15*(9), 4765-4774.
[3]. Machida T., Owen E. L., Ferrero A, and Sasdelli R, 2011, IEEE Recommended Practice and Requirements for Harmonics Control in Electrical Power Systems. IEEE Std. 519-1992, IEEE – Institute of Electrical and Electronic Engineering, USA.

[4]. IEC 61000-4-34, Ed 1 2009, “Steady-state Analysis of the Series Resistance-inductance Circuit Controlled by Silicon Controlled Rectifiers,” *IEEE Transactions on Industry Applications*

[5] IEEE Std. 519: July 2010 International Review of Electrical Engineering 5(4):1444-1451

[6] Golkar, M.A., "Electric Power Quality: Types and Measurement", IEEE International Conference on Electric Utility Deregulation, Restructuring & Power Technologies, 2004.

[7] Gour, D., Dohare, D. and Saxena, A., "A Study of Various Filters for Power Quality Improvement",

[8].http://web.ecs.baylor.edu/faculty/grady/Understanding_Power_System_Harmonics_Grady_April_2012.pdf.

[9].http://ewh.ieee.org/soc/e/sac/itee/itee/public/old_issue/vol02iss04/MEEM020403.pdf;

[10]. http://www.slideshare.net/backam78/power-quality-inelectricalsystems2007 .