International Journal of Engineering Research Updates

Journal homepage: https://orionjournals.com/ijeru/

ISSN: 2783-0187 (Online)

ORION SCHOLAR JOURNALS

(RESEARCH ARTICLE)

Check for updates

Electrical load flow analysis of Auchi distribution network without load shedding

Micheal Rotimi Adu [1], Isah Osilama Oshiobugie [1] and Tolulope David Makanju [2,*]

[1] The Federal University of Technology Akure, Ondo State Nigeria.
[2] Achievers University Owo, Ondo State Nigeria.

International Journal of Engineering Research Updates, 2023, 04(02), 035–044

Publication history: Received on 08 February 2023; revised on 07 April 2023; accepted on 10 April 2023

Article DOI: https://doi.org/10.53430/ijeru.2023.4.2.0020

Abstract

The occurrence of loadshedding under normal operating condition in Distribution Network caused a lot of inconveniences to the consumer. However, there is need to examine the state of the distribution network to know the performance without load shedding under normal condition. This research examines the state of Auchi distribution network without load shedding. In order to achieve the aim of the research data was obtained from the distribution company, the modelling of the distribution network obtained was done using ETAP and the load flow simulation was done using Newton Raphson Algorithm to determine the power flow in the network, Bus voltage, losses along the line and transformer losses. The results of the study show that at 80% loading of the transformers in the network, the voltage supply to the consumer is bad under normal condition, since the two out of three 33 kV bus voltages is below the acceptable range of plus or minus 5% of the nominal voltage. Likewise, almost all 11 kV and 0.415kV voltages in the network is below the acceptable limit of plus or minus 10% of the nominal voltage. Furthermore, the result indicates that active power loss in the network is 0.2MW which is very high. This research therefore recommends that the voltage profile of AUCHI distribution network needs improvement in order to improve the quality of supply. Also, since the supply from the grid is be allocated based on the generating capacity this research also recommends that DISCO in charge of Auchi distribution network should also considering the usage of DG in the network which can perform a dual purpose of voltage improvement and addition of power supplied.

Keywords: Load; Distribution; Voltage; Quality

1. Introduction

Electrical energy has been the major challenge to Nigeria citizens. It has been reported by [1] that electrical energy is a key determinant for economy growth. Electricity sector of Nigeria is divided into three, which are Generation sector, Transmission sector and distribution sector, the activities of all these sectors are coordinated by a regulating agency called Nigeria Electricity Regulating Agency (NERC). However, with the effort of NERC to ensure reliable supply of electricity to consumer a lot of towns in Nigeria are still not having a stable supply of electricity [2].

The operation of Distribution companies (DISCOS) in Nigeria in term of hours of supply to consumer is based on the tariff band the consumer is placed, this tariff band is been determined by the location of the transformer [3]. The estimated hours of supply to each tariff band for non-maximum demand is presented in Table 1.

* Corresponding author: Tolulope David Makanju

Table 1 The estimated hours of supply to each tariff band for non-maximum demand

Tariff Band	Minimum Hour of Electricity Supply	Amount for 1kwh (#:k)
A	20 hours	56:28
B	16 hours	54:13
C	12 hours	50:65
D	8 hours	33:20
E	4 hours	32;88

The table 1, indicated that the DISCOS tend to serve citizens in tariff band A better compared to others. However, NERC only enforce laws on Discos based on the availability of supply to citizens but not quality of the supply. Majority of the location are faced with bad quality of supply which caused by several factors such as Impedance of the 11kV line, the distance of the distribution line, loading of transformer etc. Since there is no specified index used to regulate the load of consumer on a particular transformer, the random approach used by distribution company in Nigeria leads to overloading of a transformer. According to [4] in sizing of transformer 25% future expansion tolerance should be allowed in the design. Many organizations and individuals as subscribed to the use of generator because of the problem of voltage quality which as caused organizations and individuals to loss expensive equipment's. However, the cost of running on generator by individuals is not convenient for the consumer and also the pollution caused to the environment tends to caused global warming [5, 6]. The state of any distribution network can be determined using load flow approach to avoid irregularities in quality of voltage supply to the consumer. However, there are several methods used to solve the load flow problem, including the Gauss-Seidal, Newton-Raphson, and Fast Decoupled load flow approaches which are iterative in nature. In recent years advancements in the search for digital computer solutions for the load flows of power systems by increasing the accuracy and rate of convergence of numerical-solution approaches [7]. The voltage magnitudes and angles at each bus in the steady state can be found from the load flow studies. It is possible to calculate the actual and reactive power flow over each line once the bus voltage magnitudes and their angles have been calculated using the load flow. With Newton-Raphson, PV buses means that there are fewer unknown variables we need to calculate explicitly and less equations we need to satisfy explicitly Contrast to Gauss iterations where PV buses complicated the algorithm. In Nigeria most of the transformers in distribution network operates at 80% of its rated capacity, but the availability of supply to consumer is determined based on the allocation given to the distribution company by Transmission company which led to load shedding. However, with the occurrence of load shedding in the distribution network many consumers still experience poor quality of supply. Many research has been carried out on the power network in Nigeria and a lot of recommendation has been made for better improvement. It is therefore important to determine the state of the distribution network if loadshedding is not allow during normal operating condition in the network. This research considered the load flow of Auchi distribution network without load shedding in the network.

2. Material and method

The objective of this research work was achieved by collecting necessary data of AUCHI distribution network which include network diagram, loading on each transformer, distance between the transformer, transformer rating, the height of the pole. The loading of the transformer is 80% . The network obtained was modelled using ETAP and the balanced load flow analysis was carried out using Newton Raphson Algorithm presented in equation (1) to equation (7).

The complex form for Newton Raphson algorithm is presented in

$$S_I = P_i + jQ_i \text{………………..}(1)$$

$$S_I = V_i . I_i^* = V_i (\textstyle\sum_{K=1}^{N} Y_{ik} V_k)^* \text{………………..} (2)$$

$$S_I = V_i . \textstyle\sum_{k=1}^{n} Y_{ik}{}^* V_k{}^* \text{………………..} (3)$$

$$\text{Let } Y_{ik} = E_{ik} + JG_{ik}\pi r^2$$

$$S_i = |V_i||V_k| e^{j\emptyset_{ik}} (E_{ik} - jG_{ik}) \text{ ………………..} (4)$$

$$S_i = \sum_{k=1}^{n} |V_i||V_k|(cos\emptyset_{ik} + jsin\emptyset_{ik})(E_{ik} - jG_{ik}) \quad \ldots\ldots\ldots\ldots\ldots\ldots (5)$$

Let

$$\emptyset_{ik} = \emptyset_i - \emptyset_k$$

The reals power and reactive power from equation (5) can been computed as in equation (6) and (7)

$$P_i = \sum_{k=1}^{n} |V_i||V_k|(M_{ik}cos\emptyset_{ik} + N_{ik}sin\emptyset_{ik}) \ldots\ldots\ldots\ldots\ldots\ldots (6)$$

$$Q_i = \sum_{k=1}^{n} |V_i||V_k|(M_{ik}sin\emptyset_{ik} + N_{ik}cos\emptyset_{ik}) \ldots\ldots\ldots\ldots\ldots\ldots (7)$$

Where P_i and Q_i are the active and reactive power at bus i, v_i and vk are the voltage at bus i and k respectively, Si, is the apparent power Y_{ik} is the admittance between the line., Ø is bus angle between.

Since load is a dynamic parameter the fuse rating of the secondary rating which determine the maximum loading on each transformer was used to obtained the secondary side loading of the transformer which was 80% of the transformer rating. The simulation was done assuming there is no load shedding in the network. The following parameters were determined the power flow at each bus, voltage at each bus, power factor, line losses and transformer losses.

3. Results and discussion

The load flow analysis of the AUCHI distribution network considering the two feeders associated to the town is presented. The results of the voltage at each Bus (33kV, 11kv, 0.415kV) in the network under the 80% loading of the transformer in presented in Figure 1, Table2 and 3. The voltage profile at the three 33kV bus falls within the permissible limit of plus or minus 10% as the percentage voltage at each Bus is 100%, 97% and 95% loading this means the voltage on each 33kV of the network is of good quality.

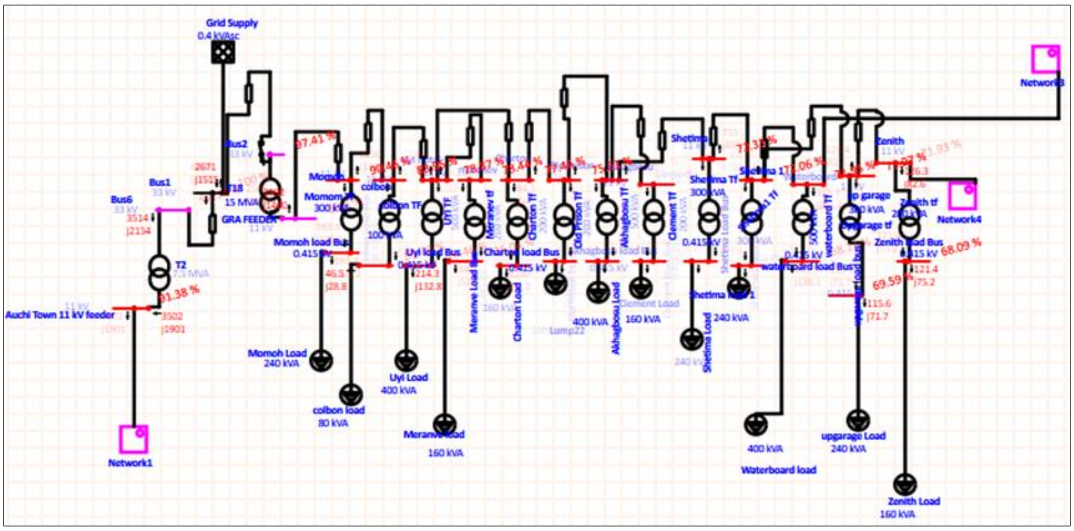

Figure 1 Simulation of Auchi Distribution Network under 80% loading

Table 2 33kV Operating BUS voltage at 80% Loading

Bus ID	Nominal kV	Operating Voltage
Bus1	33	33
Bus2	33	32.147
Bus6	33	31.198

Table 3 11kV and 0.415 KV Operating BUS voltage at 80% loading

Bus ID	Nominal kV	Operating Voltage
11 kV		
Akhagbosu	11	8.105
Arafrat Mosque	11	9.668
Auchi Town 11 kV feeder	11	10.052
Bank	11	9.021
Charton	11	8.52
Clement	11	8.1
colbon	11	9.234
Constance2	11	8.306
Dascoli	11	8.679
GRA FEEDER	11	10.593
Hill Top	11	9.918
Igelefor2	11	8.129
meranev	11	8.628
Momoh	11	9.95
Oki Village2	11	7.919
Old Prison	11	8.306
Olele Junction	11	8.836
Otaru Road2	11	8.437
Presto2	11	7.935
setraco Junction2	11	8.155
Shetima	11	7.956
Shetima 1	11	7.927
Teacher college2	11	7.968
Total2	11	8.41
UBA Junction	11	9.231
up garage	11	7.917
Usogun Road2	11	8.045
Uyi hotel	11	8.675
Waterboard	11	7.914
Zenith	11	7.912
0.415 kV		
Akhagbosu load Bus	0.415	0.311
Arafat load Bus	0.415	0.373
Bank load Bus	0.415	0.362

bishop court load	0.415	0.3
catholic Church Load Bus1	0.415	0.299
Charton load Bus	0.415	0.32
Clement load Bus	0.415	0.305
colbon Load Bus	0.415	0.343
Constance Load Bus2	0.415	0.337
Dacoli load Bus	0.415	0.348
Garu Load Bus4	0.415	0.298
GNL 5star load Bus1	0.415	0.299
Hill Top Load Bus	0.415	0.375
Igelefor Load Bus2	0.415	0.335
Meranve Load Bus	0.415	0.325
Momoh load Bus	0.415	0.362
ogele load Bus	0.415	0.355
Oki Load Bus2	0.415	0.332
Old Prison Load	0.415	0.315
Otaru Load Bus2	0.415	0.342
Presto Load Bus2	0.415	0.332
Sentraco Load Bus2	0.415	0.336
Shetima Load Bus	0.415	0.309
Shetima1 load Bus	0.415	0.306
Teacher College BUS2	0.415	0.333
Tee-pee load Bus1	0.415	0.3
Total Load Bus2	0.415	0.342
UBA load Bus	0.415	0.367
upgarage load bus	0.415	0.304
Usogun Load Bus2	0.415	0.334
Uyi load Bus	0.415	0.325
Water latake load Bus1	0.415	0.299
waterboard load Bus	0.415	0.298
Zenith load Bus	0.415	0.299

Further the analysis presents the 11kV Bus voltage in the network as shown in Table 3, the results indicate that Bus voltage of different location in the network is below the 10% permissible, this may be due to the distance of the transmission line, the loading on the bus, also the impedance of the transmission line. The operating voltage reaching the distribution transformer is lower than the nominal voltage of 11 kV in the network. this implies that consumers or users tends to experience bad voltage quality. In order to verify the voltage received by the by the consumer the low voltage (0.415kV) profile is also presented in Table 3. The result shows that at the peak loading of transformer that is 80% loading considered in this research majority of the users or consumer tends to have poor quality of voltage which will not be suitable for the user. This voltage can also lead to damage of equipment. However, the load shedding in the network helps to overcome the issue of low voltage because all the network are not powered at the same time. The intent of this research is to improve the availability of electricity supply to consumer in AUCHI distribution Network. With the analysis of the voltage the AUCHI distribution network cannot have high availability of supply, even if the availability is given the quality of supply will be bad.

Furthermore the load flow analysis from Bus to Bus in the network is presented in Table 4, this will helps to determine the var generated into each Bus in the Network which may help to determine were compensator is needed.

Table 4 Active and Reactive Power loading at each Bus in the Network

Bus ID (33kV)	**kW Loading**	**kvar Loading**
Bus1	6408.7	3702.1
Bus2	2595.5	1523.7
Bus6	3514.2	2154.4
Bus ID (11kV)	kW Loading	kvar Loading
Akhagbosu	1296.2	825.7
Arafrat Mosque	3096.2	1685.4
Auchi Town 11 kV feeder	3501.6	1901.2
Bank	2530.9	1466
Charton	1554.7	938.4
Clement	126.8	82.69
colbon	2079.6	1219.9
Constance2	1386.3	855.3
Dascoli	2081.8	1243.6
GRA FEEDER	2592.3	1460.1
Hill Top	3462.3	1862
Igelefor2	203.5	130.3
meranev	86.86	55.52
Momoh	2422.5	1394.5
Oki Village2	204.5	131.2
Old Prison	1421.5	881.2
Olele Junction	2370.3	1400
Otaru Road2	1861	1142.3
Presto2	401.4	257
setraco Junction2	1227	770.6
Shetima	941.2	610.6
Shetima 1	751.2	488.8
Teacher college2	606.5	387.1
Total2	222	142.2
UBA Junction	2865.9	1637
up garage	244.9	158.5
Usogun Road2	811.3	513.7

Uyi hotel	1897.7	1137.6
Waterboard	315.7	206.4
Zenith	126.3	82.57
BUS ID (0.415kV	kW Loading	kvar Loading
Akhagbosu load Bus	199.5	123.6
Arafat load Bus	56.34	34.91
Bank load Bus	94.38	58.49
Charton load Bus	82.62	51.21
Clement load Bus	122.1	75.66
colbon Load Bus	46.53	28.84
Constance Load Bus2	126	78.06
Dacoli load Bus	146.7	90.91
Hill Top Load Bus	260.9	161.7
Igelefor Load Bus2	198.8	123.2
Meranve Load Bus	84.94	52.64
Momoh load Bus	163.3	101.2
ogele load Bus	233.8	144.9
Oki Load Bus2	199.5	123.6
Old Prison Load	80.36	49.8
Otaru Load Bus2	217.7	134.9
Presto Load Bus2	191.7	118.8
Sentraco Load Bus2	191.9	119
Shetima Load Bus	179.1	111
Shetima1 load Bus	182.2	112.9
Teacher College BUS2	197.9	122.6
Total Load Bus2	216.7	134.3
UBA load Bus	253.3	157
upgarage load bus	115.6	71.66
Usogun Load Bus2	192.5	119.3
Uyi load Bus	214.3	132.8
waterboard load Bus	303.5	188.1
Zenith load Bus	121.4	75.24

The results show the loading on the 33kV BUS the result indicates that the Var generated at BUS 6 in the Network is high which caused a significant voltage drop on the Bus. However, the Kvar supplied at BUS 1 of the network is higher to maintain the voltage within a permissible range as the operating voltage is same as the nominal voltage. Likewise the results shows the power flow from the 11 kV network which shows that majority of the BUS in the network operating at a low voltage profile as a results of low reactive power been supplied to the BUS. This suggestion that in order to improve the reliability of supply to AUCHI distribution network without loadshedding of any of the feeder, the voltage at each Bus most be improve to an acceptable limit by either increasing the Var supplied to each Bus. Likewise, the investigation of the voltage at the 415 V Bus to the consumer shows that majority of the consumer experience load voltage as the Var generated.

Furthermore, the analysis also considered the losses in the network due to impedance of the line and internal losses that occurred in the transformer. The results presented in Table 5, shows that the major significant losses occurred with the line as the transformer losses can be considered negligible to the losses that occurred within the transmission line. However, the total active power and reactive power losses 1725 kW and 806kVar respectively which is higher in the network.

Table 5 Reactive and Active losses in the Network

ID	Bus 1	Bus 2	kW Losses	kvar Losses
Akhagbosu Tf	Akhagbosu	Akhagbosu load Bus	4.81	7.22
Akhagbosu-clement	Akhagbosu	Clement	0.105	0.005
Akhagbosu-shetima	Shetima	Akhagbosu	23.86	1.58
Arafat Mosque	Arafrat Mosque	Arafat load Bus	1.35	2.02
Auchi Teacher Tf2	Teacher college2	Teacher College BUS2	4.91	7.36
Charton Tf	Charton	Charton load Bus	1.86	2.79
Charton-oldprison	Old Prison	Charton	48.66	3.24
Clement Tf	Clement	Clement load Bus	4.69	7.03
colbon TF	Colbon	colbon Load Bus	1	1.5
Constance Tf2	Constance2	Constance Load Bus2	3.04	4.57
Dascoli TF	Dascoli	Dacoli load Bus	3.8	5.7
HP	Hill Top	Hill Top Load Bus	5.45	8.17
Igelefor tf2	Igelefor2	Igelefor Load Bus2	4.75	7.12
Line1	Auchi Town 11 kV feeder	Hill Top	39.28	39.25
Line2	Hill Top	Arafrat Mosque	99.7	6.64
Line3	UBA Junction	Arafrat Mosque	172.6	11.49
Line4	UBA Junction	Bank	75.7	5.04
Line5	Olele Junction	Bank	64.06	4.27
Line6	Dascoli	Olele Junction	49.19	3.27
Line25	Shetima 1	Shetima	3.84	0.254
Line26	Waterboard	Shetima 1	0.682	0.0436
Line27	up garage	Shetima 1	0.407	0.0253
Line28	Zenith	up garage	0.109	0.0054
Line53	Total2	Otaru Road2	0.943	0.0561
Line54	Igelefor2	setraco Junction2	0.902	0.0533
Line55	Presto2	Oki Village2	0.565	0.0339
Line56	Teacher college2	Presto2	2.27	0.148
Line57	Usogun Road2	Teacher college2	7.83	0.516
Line58	setraco Junction2	Usogun Road2	14.96	0.991
Line59	setraco Junction2	Constance2	30.3	2.01

Line60	Constance2	Otaru Road2	28.84	1.92
Line61	Otaru Road2	Dascoli	70.34	4.68
Meranev tf	Meranev	Meranve Load Bus	1.92	2.87
Momom TF	Momoh	Momoh load Bus	3.54	5.31
Old Prison Tf	Old Prison	Old Prison Load	1.85	2.78
oldprison- Akhagbosu	Akhagbosu	Old Prison	43.15	2.87
Olele	Olele Junction	ogele load Bus	5.55	8.33
Otaru Tf2	Otaru Road2	Otaru Load Bus2	5.29	7.93
Presto Hotel2	Presto2	Presto Load Bus2	4.64	6.95
Shetima Tf	Shetima	Shetima Load Bus	6.98	10.48
Shetima1 Tf	Shetima 1	Shetima1 load Bus	7.3	10.95
Station-Momoh	GRA FEEDER	Momoh	169.8	65.63
Station-Momoh3	Colbon	Momoh	176.1	68.03
Station-Momoh5	Colbon	Uyi hotel	134.4	51.99
Station-Momoh7	Bus2	Bus1	75	-8.48
Station-Momoh8	Bus1	Bus6	224	32.59
T2	Bus6	Auchi Town 11 kV feeder	12.66	253.1
T5	setraco Junction2	Sentraco Load Bus2	4.38	6.58
T6	Oki Village2	Oki Load Bus2	5.06	7.58
T18	Bus2	GRA FEEDER	3.18	63.56
Total Tf2	Total2	Total Load Bus2	5.28	7.91
UBA	UBA Junction	UBA load Bus	5.97	8.96
UBA Bank	Bank	Bank load Bus	2.17	3.25
Upgarage tf	up garage	upgarage load bus	2.83	4.24
Usogun Tf2	Usogun Road2	Usogun Load Bus2	4.54	6.81
UYI TF	Uyi hotel	Uyi load Bus	4.83	7.24
Uyi-charton	Uyi hotel	Charton	36.34	3.63
Uyi-meraven1	Meranev	Uyi hotel	0.642	0.0091
waterboard Tf	Waterboard	waterboard load Bus	12.2	18.3
Zenith tf	Zenith	Zenith load Bus	4.88	7.32
TOTAL			1735	806

4. Conclusion

The AUCHI distribution network has been studied under 80% loading of the transformer without loadshedding for high availability of supply. The findings of this study revealed that with the presents network Auchi distribution network cannot supply a good quality of supply to the consumer without loadshedding. The present situation is of the network as caused consumer to be running on other sources of power supply. This research therefore recommends that the voltage profile of AUCHI distribution network needs improvement in order to improve the quality of supply. Also, since the supply from the grid is be allocated based on the generating capacity this research also recommends that DISCO in charge of Auchi distribution network should also considering the usage of DG in the network which can perform a dual purpose of voltage improvement and addition of power supplied.

Compliance with ethical standards

Acknowledgments

We like to knowledge the support of Benin Electricity Distribution company for the provision of Data used for the research.

Disclosure of conflict of interest

There is no conflict of interest among the author's.

References

[1] Emodi NV, Improving Electricity Access in Nigeria: Obstacles and the Way Forward. International Journal of Energy Economics and Policy 2015 5(1): 335-351.

[2] Titus KO, Abdul-Ganiyu AJ, Phillips DA. The current and future challenges of electricity market in Nigeria in the face of deregulation process. African Journal of Engineering Research 2013 1(3): 33-2WVol. March; 1(3), pp. 33-39.

[3] Nigeria Electricity supply Industry (NESI). Available athttps://nerc.gov.ng/index.php/home/myto/408-distribution-end-user-tariff assess on 20th January, 2023.

[4] Oyeleye MO, Itodo ES, Dare A. Design of Effective 33/11 kV Injection Substations Using International Standards. Journal of Applied Science & Process Engineering 2022. 8(2):977-985 DOI:10.33736/jaspe.3625.2021.

[5] Makanju T D, Oluwalana OJ. A Novel Methodology For Modelling PV Module Based On Monitored Data. Journal of Multidisciplinary Engineering Science Studies 2020. March 6(3): 3072-3076.

[6] Ale TO, Rotipin KJ, Makanju TD. Temperature Effects on Optimal Performance of PV Module. Journal of Engineering Advancements. 2022, 3(04), 162–165. https://doi.org/10.38032/jea.2022.04.004.

[7] Afolabi O, Ali W, Cofie P, Fuller J, Obiomon P, Kolawole E. Analysis of the Load Flow Problem in Power System Planning Studies. Energy and Power Engineering (2015) 7(1), 509-523. doi: 10.4236/epe.2015.710048.