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Investigation of Power Quality Issues in South–Eastern Nigeria Power System

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ABSTRACT: *This paper is aimed at investigating power quality issues in the South – East Nigeria power system. In order to achieve these goals, questionnaires were distributed to a sample of one hundred electricity consumers as well as twenty utility staff and interviewed in addition to collecting peak voltage logs on the feeders from Egbu sub-transmission substation by the researcher and field data collectors. The rating scale and statistical methods were used to process the obtained data. The quality of voltage deviations from the 33kV and 11kV feeders indicated notable deviations from the expected values. From the results, the utility companies and their customers trade blames with each other concerning the origin of poor power quality. While 39% of customers interviewed blamed the utility, 33% of the utility staff blame power consumers.*

KEY WORDS: *power quality, voltage sag, voltage swell, south-eastern Nigeria, utility, customer*

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I. INTRODUCTION

Power quality (PQ) is certainly a major concern in the present day Nigeria. It becomes, especially, important with the introduction of sophisticated devices whose performance is very sensitive to the quality of power supply**.** Modern industrial processes are based on large amounts of electronic devices such as programmable logic controllers and adjustable speed drives. The electronic devices are very sensitive to disturbances and thus industrial loads become less tolerant to power quality problems such as voltage dips, voltage swells, and harmonics [1]**.** Importance of electricity is aptly captured in the moans of electricity consumers in Nigeria whenever there is an interruption in power supply as well as their shouts of joy when power is restored.

Electronic equipment is a very sensitive load to harmonics because their controls depend on either the peak value or the zero crossing of the supplied voltage, which are all influenced by the harmonic distortion [2]. Electrical energy is a product and, like other products, should satisfy power quality requirements of the consumers. The ability of the power system to deliver electric power without interruption is termed one hundred percent reliability, while the ability to deliver a clean signal without variations in the nominal voltage or current characteristics is termed high power quality [3]. The power quality of a system expresses to which degree a practical supply system resembles the ideal supply system. If the power quality of a system is good, then any load connected to it will run satisfactorily and efficiently. On the other hand, if the power quality of the network is bad, then any loads connected to it will fail or will have a reduced lifetime, and the efficiency of the electrical installation will reduce.

There are many ways in which electric power can be of poor quality and many more causes of such poor quality power in Nigeria. The electric power industry comprises electricity generation (AC power), electric power transmission and ultimately electricity distribution to an electricity meter located at the premises of the end user of the electric power. The complexity of the system to move electric energy from the point of production to the point of consumption combined with variations in weather, generation, demand and other factors provide many opportunities for the quality of supply to be compromised. While "power quality" is a convenient term for many, it is the quality of the voltage—rather than power or electric current—that is actually described by the term.

Power outages assumed a very high embarrassing dimension in Nigeria. In Nigeria power outage for several days is common and could happen just anywhere. In 2009, the presidential palace was not spared and power outage became so frequent that ever since, the state house is powered 24 hours with generators [4]. The FIFA Under-17 world cup played in Nigeria in 1999 really occasioned some embarrassing moments when some of thevenues were thrown into darkness. The Murtala Mohammed International Airport, Lagos is not spared despite being the main gateway in and out of the country. Furthermore, it has been shown that small and medium scale enterprises (SMEs), including macro – businesses are the highest employers of labour in Nigeria [5]. One of the major challenges of SMEs in Nigeria is the high cost of electricity generation from private electricity power generators [6] as a result of inadequate and erratic supply or more generally, poor power quality from the public utility. Consequently, many entrepreneurs who cannot afford the outlay of "self – generation" have been pushed out of business. In addition, poor power quality in the form of erratic and inadequate power supply has been the major reason cited by many of the multinationals that either closed down or wound up their operations in Nigeria which further worsened the level of unemployment [7]. For instance, the exit of Michelin from Nigeria cost the economy 1,300 direct jobs. In the midst of all this, Nigeria's demand for energy and electricity is increasing rapidly. This becomes more worrisome when considered against the backdrop of Nigeria's Vision 20-20-20 (i.e. to be among the twenty most industrialized countries by the year 2020) [8].

The aim of this work, therefore, is to investigate the various power quality issues in the Nigerian power system, using the South – Eastern Nigeria as a case study, their effects on both the utility's and consumers' sides of the power system with emphasis on voltage swells, sags and interruptions. This work attempted to identify the main cause(s) of poor power quality in Nigeria, find out where the power quality issue(s) emanate from: whether from the utility side or the consumers' side, use a statistical approach to investigate the power quality for one year (2012) using the engineering software tool, MATLAB and Microsoft Excel. This will provide a reference material for engineers and electronic equipment manufacturers to fall back on for decision making purposes.

1.1 Causes Of Power Quality Issues

Power Quality issues are mainly due to increased use of power electronic devices, nonlinear loads and imbalance in power systems. Dynamic loads cause power quality problems usually by voltage or current variations such as voltage dips, fluctuations, momentary interruptions, oscillatory transients, harmonics, harmonic resonance etc.[9]. Power quality is simply the interaction of electrical power with electrical equipment. If electrical equipment operates correctly and reliably without being damaged or stressed, we would say that the electrical power is of good quality. On the other hand, if the electrical equipment malfunctions, is unreliable, or is damaged during normal usage, we would suspect that the power quality is poor [9]. There are two approaches to the mitigation of power quality problems. The solution to the power quality can be done from customer side or from utility side. First approach is called load conditioning, which ensures that the equipment is less sensitive to power disturbances, allowing the operation even under significant voltage distortion. The other solution is to install line conditioning systems that suppress or counteracts the power system disturbances [10].

Power quality is a determination of the quality of the voltage in a circuit. It can also mean the study of the sources, effects and control of disturbances which propagate via the electric power supply system. The disturbances change the supply RMS voltage or its wave shape (or very occasionally the frequency).

Power quality determines the fitness of electrical power to consumer devices. Synchronization of the voltage frequency and phase allows electrical systems to function in their intended manner without significant loss of performance or life. The term is used to describe electric power that drives an electrical load and the load's ability to function properly. Without the proper power, an electrical device (or load) may malfunction, fail prematurely or not operate at all. There are many ways in which electric power can be of poor quality and many more causes of such poor quality power [4].

Ideally, AC voltage is supplied by a utility as sinusoidal having an amplitude and frequency given by national standards (in the case of mains) or system specifications (in the case of a power feed not directly attached to the mains) with an impedance of zero ohms at all frequencies [3].

Each of these power quality problems has a different cause. Some problems are a result of the shared infrastructure. For example, a fault on the network may cause a dip that will affect some customers; the higher the level of the fault, the greater the number affected. A problem on one customer's site may cause a transient that affects all other customers on the same subsystem.

Nigeria is one of the countries with the biggest gap between supply and demand for electricity in the world. The supply of electricity in Nigeria is just above 4000MW for a population of 150 million people [7], a supply which is never adequate to stimulate economic growth for a country with a demand growth of 8.2% [8]. Going by the roadmap implementation record, additional 7,770MW of electricity would have been added to the current 3800MW by the endof2013.

2.4 Characteristics Of Power Supply Quality In Nigeria

The electric power supply industry in Nigeria is characterized by epileptic power supply, instability of power supply, low voltage, high voltage, among others.Problems that influence power quality in Nigeria which occur at different stages of power supply can be divided into generation, transmission and distribution. For generation, the problems include insufficient power generating stationand lack of maintenance culture, gas constraints, and poor technological development. Also, change in weather condition may lead to: (a) Inadequate inflow of water into the reservoirs of the hydro-generating stations. When the water level is very low, the potential of water reduces. During this period, only the machines with variable blades are suitable for this condition and there will be complete shutdown of fixed blade machines to prevent them from being damaged;

(b) The harmattan and dry season also affect the operation of the gas turbines as high exhaust temperature and clogging of air inlet filters cause forced shutdown of the gas turbine during harmattan season while the performance of the steam power plants is affected by the quantity of cooling water.

In the transmission system, the problems facing them include vandalism, bush burning, lack of modern testing equipment, storms and lightning strike, construction activities and accidents, trees growing under transmission lines, and noncompliance of operators. Problems facing power distribution are overloading of equipment, corruption, power wastage, defective appliances, poor installation of electrical appliances, among others. Figure 1shows a damaged 11kV distribution line in Umuahia, Nigeria.

Fig. 1: Damaged distribution cables caused by a felled tree falling on distributors along Bende Road Umuahia, 13 March, 2016.

The effects of these aforementioned poor power quality problems have serious implication on the utilities and customers.

Utility side records higher losses in transformers, cables, etc. In conductors, the neutral wires can burn due to the presence of third harmonics generated by non – linear loads. The power factor correction capacitors may puncture due to resonant conditions at resonant frequencies near lower order harmonics. The energy – meters, which are calibrated to operate under pure sinusoidal conditions, may give erroneous readings. The solid – state protective relays can mal – operate due to poor power quality. There can be increased losses in cables, transformers and conductors.

The customer side of the power network also experiences adverse effects of poor power quality. The automatic processes employing adjustable speed drives may shut down because of nuisance tripping due to even short voltage sags. Induction and synchronous motors can have increased copper and core losses, pulsating torques and overheating with duration effect.

The non – sinusoidal power supply thus reduces torque and efficiency of the motors. The computers and telecommunication equipment encounter loss of data and mal-operation due to poor power supply quality. The domestic electronic gadgets such as digital clocks, VCRs and TVs are also affected by voltage distortions.

The mitigation of PQ problems may take place at different levels, namely transmission, distribution and the end use equipment. As seen in Fig. 2, several measures can be taken at these levels.

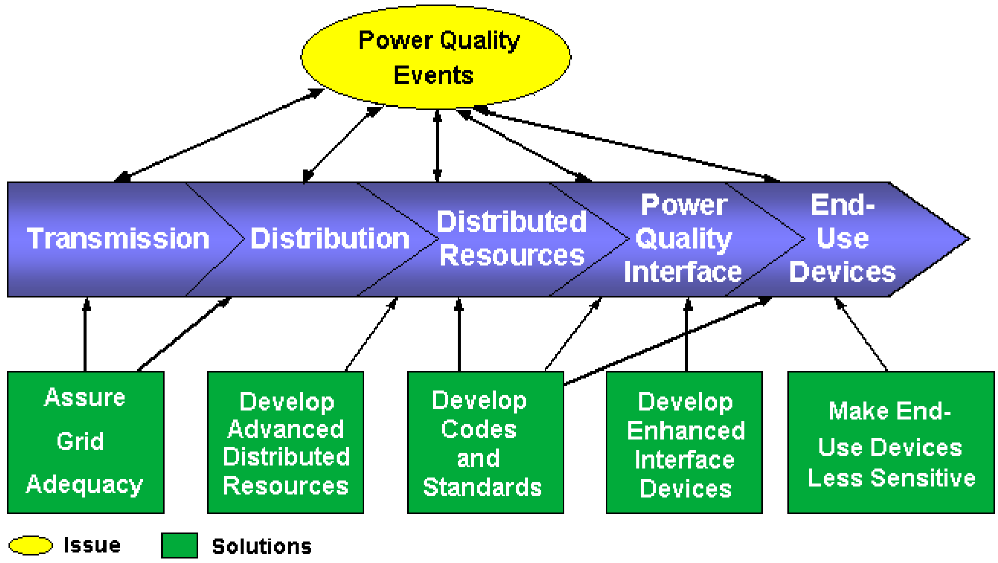

Fig. 2: Mitigation of Power Quality Problems [10]

II. MATERIALS AND METHODS

This paper used a statistical approach to investigate the power quality issues in South – Eastern Nigeria for one year (2012). A questionnaire was deployed to obtain information from both consumers and utilities. Also, 33kV and 11kV distribution lines were studied. The results obtained were generalized for the entire South - East. MATLAB and Microsoft Excel were used to process the peak voltage on each of the feeders against time. Appropriate deductions were drawn from the graphs. The pie charts displayed the results of the questionnaire in order to determine the origin of the power quality problems.

In order to characterize the actual present state of power quality in the South – Eastern Nigeria, one hundred questionnaire forms were distributed to the consumers. This has sections for industrial, commercial and residential consumers. Also, twenty questionnaire forms were distributed to utility companies. Both the utility companies and their customers were questioned so as to ascertain that the quality of service offered by the public utility matched what the customers received.Oral interviews were conducted on the utility as well as the industrial, commercial and residential customers. This afforded more pieces of information which the questionnaire could not have covered for the sake of brevity.

3.1 Data Collection Methods

The Egbu 132kV sub-transmission substation was visited to obtain the monthly transformer peak load and current as well as the voltage variations for the year 2012. Two industries were visited in Aba, Nigeria to witness to what extent their businesses depended on quality power supply. The packaging, production, laboratory & testing, engineering, and storage units of the companies were visited.

Data obtained from questionnaires is presented with the aid of pie charts after careful analysis of the responses. This aided this author to realize one of the purposes of the study: to answer the question, "Where does the Power Quality issue majorly emanate from in the power system; from the utility's side or the customers' side?"

3.2 Data Analysis

The Rating Scale method [9, 10] was employed in analyzing the responses obtained from the questionnaire forms. In this method, each response type is assigned a rating scale. At the end of the survey the weight of each response is obtained by multiplying the scale by the number of respondents that chose that particular response type. Scales are awarded to the responses taking the weight of each response into consideration as follows: Strongly disagree (SD) = 1, Disagree (D) = 2, Neutral (N) = 3, Agree (A) = 4, Strongly agree (SA) = 5.

As an illustration, consider the question and response in Table 1.

Table 1: Showing an approximation of what results might look like later with responses (in parenthesis):

Question 1	Strongly disagree	Disagree	Neutral	Agree	Strongly Agree
The presentation was great.	11% (1)	0% (0)	33% (3)	33% (3)	22% (2)

The numbers in parentheses are the weighted values assigned to the columns. The number multiplied with the weighted value is the respondent count or the "frequency" of those that picked that rating:

[1*(1) + 0*(2) + 3*(3) + 3*(4) + 2*(5)] = 32

- We see that "the presentation was great" row choice had "1" respondent pick **Strongly Disagree**. Since the number of respondents that picked that rating is "1" and the weighted value is assigned a "1", we have [1*(1)] as the 1st part of the equation.
- Next for the **Disagree** column, you see that "0" respondents picked that choice and the column weighting is "2." For this 2nd part of the equation, we have [0*(2)].
- This process continues through to the end of the equation for each frequency and for each weighted value.
- After multiplying the weighted values with the actual number of respondents who picked that rating, the sum the totals is 32.

Then, we'll add the respondent totals (or frequency number) of those that picked the ratings. In this example, it is total of the numbers that are not in parentheses: (1 + 0 + 3 + 3 + 2) = 9

Last, we are able to obtain the rating average by dividing the sum of the weights by the sum of the number of responses, i.e.,

= [1*(1) + 0*(2) + 3*(3) + 3*(4) + 2*(5)] / (1 + 0 + 3 + 3 + 2)

= 32 / 9

= 3.56

A response rating of 3.56 means that this falls to the right of **Neutral** and closer to the **Agree** rating.

3.3 Analysis of the Graphical Approach

The voltage and current logs as well as the peak load demand of Egbu 132kV transmission sub-stations are used for analysis.The Egbu 132kV transmission sub-station stepped down varying outgoing peak line voltages feeding Umuahia, Airport, Owerri, Oguta, Okigwe, and Orlu feeders plotted against time (months) for a period of 12 months.

III. RESULTS AND DISCUSSION

4.1 Data Presentation

The results of survey carried out using the random sampling technique with the aid of questionnaire forms are presented in Tables 2 and 3.

Table 2: The results of the customers' perception of the PQ issues in the South – East Nigeria power system.

S/N	Question/Statement	Responses, Number of responses and Percentage					Total
		SA	A	N	D	SD	
1.	Power consumers' actions affect power quality.	7 (7%)	7 (7%)	20 20%	20 20%	46 (46%)	100
2.	Poor power quality originates from the Utility's side.	60 (60%)	20 (20%)	4 (4%)	8 (8%)	8 (8%)	100
3.	Natural effects contribute significantly to poor power quality.	7 (7%)	17 (17%)	16 (16%)	11 (11%)	49 (49%)	100
4.	Others (e.g. vandalism, animals falling into switchgear, etc.)	4 (4%)	14 (4%)	11 (14%)	33 (40%)	38 (36.7%)	100

Table 3: The utility's perception of the power quality issues in the South – East Nigeria power system.

S/N	**Question/Statement**	**Number of responses and percentage**					**Total**
		SA	A	N	D	SD	
1.	Power consumers' actions affect power quality.	9 (40%)	5 (25%)	3 (20%)	2 (10%)	1 (5%)	20
2.	Poor power quality originates from the Utility's side.	2 (10%)	3 (15%)	4 (20%)	6 (30%)	5 (25%)	20
3.	Natural effects contribute significantly to poor power quality.	2 (10%)	4 (20%)	5 (25%)	5 (25%)	4 (20%)	20

4.	Others (e.g. vandalism, animals falling into switchgear, etc.)	2 (10%)	5 (25%)	4 (20%)	3 (15%)	6 (30%)	20

4.2 Analysis of Questionnaire
4.2.1 The Customers' Verdict

To determine the customers' viewpoints, the questionnaire was subdivided into different sections in order to accommodate the varied views of electricity consumers (i.e. residential users, industrial users, and commercial users), and afford an insight into how electricity quality affects their activities.

When asked whether they desired constant power supply in their homes and businesses, all power consumers surveyed were affirmative but were quick to add that they did not receive the desired service. About 25% of respondents said they only received a daily average service of about 9hrs and below or none at all, for several weeks. On the quality of service they received, expectedly most respondents could not provide any specific voltage figures. However, only about 30% agreed that it was acceptable. Most times they had low voltage, they acknowledged that the service they received was often not enough to power their gadgets such as televisions, refrigerators, computers, and so on. Those appliances that are not so sensitive to poor quality of power like the electric fans and heaters often operate at much reduced efficiency. In extreme cases, it can lead to equipment damage.

A few respondents affirmed that on many occasions, they have experienced high voltages in their apartments. When questioned about what they perceived as the causes of the power quality issues, 19% fingered transformer faults which can be traced to imbalance or overloading of particular transformer phases caused by illegal connections by electricity consumers, 5% argued that the causes could be due to environmental hazards such as erosion washing away electric poles, and 18% think it could be faults on the distribution lines. In general, most respondents blame the utility companies for the power quality issues.

On the industrial and commercial sections, all the industrial and commercial outfits surveyed agreed that electricity is an undeniable lifeline to their businesses. Due to power quality and constant outage in the Nigerian power system, the large scale industries generate their own power and cutting off from the utility company. However, the small and medium enterprises (SMEs) and other budding companies depend on both utility and alternative sources of power supply. During peak production, if there is power inadequacy from the utility, they resort to alternative sources like generators and solar energy. Thus the cost of generating energy from these sources cost the industries a fortune which would not have been incurred had the utility services been reliable. For instance, during an interview with the CEO of a small industry,located at Aba Industrial Avenue, his industry spent about 36,000 Naira daily on diesel to power their generator. Even when public power supply is restored, if the power fell below about 5% of the rated voltage of their equipment, they "self – generated". According to him, it is due to the high sensitivity of their industrial equipment to frequency and voltage variations which could be inimical to the health of their equipment. Almost all those who have generators affirmed that there have been times when their alternative sources of power served as their main sources, especially during production processes. Finally, 39% of respondents named the utility, 21% believed the elements (natural causes) had a part to play and 20% replied that other causes like vandalism of power installation could play a major role.

4.2.2 The Utility's Verdict

On the other hand, all utility staff surveyed agreed that population explosion, inaccurate forecast, insufficient funding, corruption, government policies, lack of or inadequate know – how contribute in one way or the other to poor quality of service they rendered. The same number also affirmed that the Nigerian power system has no spinning reserve (not surprisingly, though, considering that generation is not even adequate), and also ticked "yes" when asked whether renewable energy generation was feasible in Nigeria. 100% of public utility staff interviewed agreed that transmission losses are quite significant; about 0.075kW/km, 33% were of the view that power quality issues are traceable to customers' actions, 21% believe the utility is not doing enough to curtail the power quality issues, while 23% attribute it to natural causes and another 23% hold that the issues emanated from other (miscellaneous) sources.

When asked about what measures the utility should take or is taking to ameliorate the power quality issues bedevilling the Nigerian power system, many staff believed that harnessing more primary energy for improved generation, upgrading, and rehabilitating and expanding power infrastructure would go a long way in improving service quality.

In the next section, the questionnaire will be analyzed statistically and presented.

4.2.3 Analysis of Customers' Perception

The raw data presented in Section 4.1 is analyzed in this section. In Table 1, the number in each cell represents the responses or respondents count and the parenthesized values are the percentages of each response to the total response per question. To obtain the weighted value for each question, the respondents count or frequency of each response type is multiplied by the rating scale assigned to the response type.

For instance, consider Question 1 in Table 1.About 10 respondents chose response type "SA" with a rating scale of 5, the weighted value of that response is 5*10 =50. Following the same procedure, the weighted values for the Questions/Statements in Table 4.1 above using the rating scale method are:

- Question/Statement 1: [(5*7) + (4*7) + (3*20) + (2*20) + (1*46)]

35 + 28 + 60 + 40 + 46

Weighted total = 209

Average Rating = sum of the weighted value / Sum of the number of responses

= 209/100

= 2.09

This falls between the **"disagree"** and **"neutral"** responses, but more on **"disagree".**

- Question/Statement 2: [(5*60) + (4*20) + (3*4) + (2*8) + (1*8)].

Weighted total = 416

Average Rating = 4.16

This falls between the **"agree"** and **"strongly agree"** responses, but more on **"agree".**

- Question/Statement 3: [(5*7) + (4*17) + (3*16) + (2*11) + (1*49)].

Weighted total = 222

Average Rating = 2.22

This lies between the **"disagree"** and **"neutral"** responses, but more on **"disagree".**

- Question/Statement 4: [(5*4) + (4*14) + (3*11) + (2*33) + (1*38)]

Weighted total = 213

Average Rating = 2.13

This falls between the **"disagree"** and **"neutral"** responses, but more on **"disagree".** The result of study asshown in Fig. 3 indicated that 20% of the customers believe that customers' actions are responsible for poor power quality, 39% think utility are responsible while 21% and 20% are of the opinion that natural factors and others, respectively are responsible.

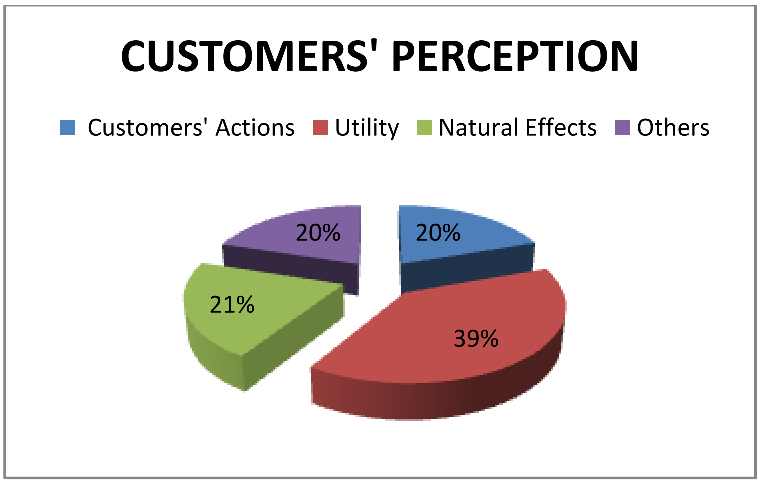

Fig.3: Customers' perception of power quality issues.

4.2.4 Analysis of Utility's Perception

Similarly, the weighted values for Table 4.2 on the utility's perception are calculated as follows:

- Question/Statement 1: [(5*9) + (4*5) + (3*3) + (2*2) + (1*1)]

Weighted total = 79

Average Rating = 79/20

= 3.95

It falls within the **“neutral”** and **“agree”** responses, but more on **“agree”** response.

- Question/Statement 2: [(5*2) + (4*3) + (3*4) + (2*6) + (1*5)]

Weighted total = 51

Average Rating = 2.55

it falls within the **“disagree”** and **“neutral”** response, but more on **“neutral”**.

- Question/Statement 3: [(5*2) + (4*4) + (3*5) + (2*5) + (1*4)]

Weighted total = 55

Average Rating = 2.75

It falls between the **“disagree”** and **“neutral”** responses, but more on **“neutral”.**

- Question/Statement 4: [(5*2) + (4*5) + (3*4) + (2*3) + (1*6)]

Weighted total = 54

Average Rating = 2.70

It falls between the **“disagree”** and **“neutral”** response but more on the **“neutral”.**

Again, the results above are displayed as shown in Fig. 4where 33% of the utility staff believe that customers’ actions are responsible for poor power quality, 21% think utility are responsible while natural factors and other factors each are responsible for 23% of the PQ problem.

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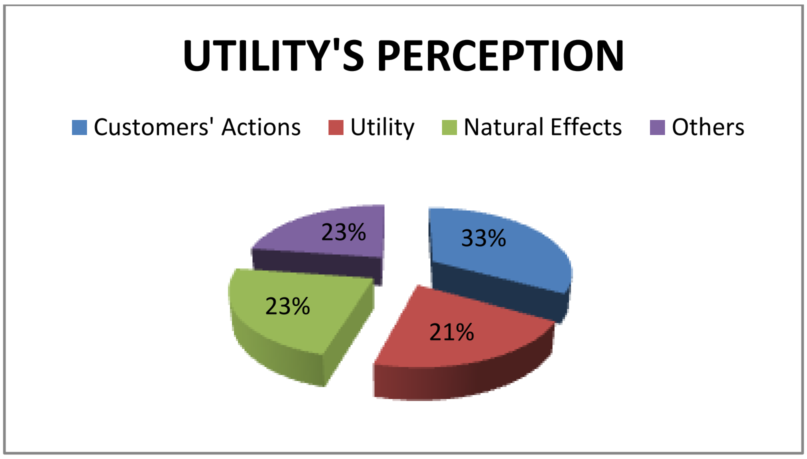

Fig 4: Utility’s perception of the power quality issues.

The pie charts of Fig. 3 and Fig.4 show the results of the study in which both electricity consumers and utility personnel were interviewed about the origin of poor power quality issues in the Nigerian power system. The utility’s and customers’ perceptions are often different, with each blaming the other. Although both blame about one – fifth of the events on natural phenomenon, such as lightning surges, customers, however, often presume that utility is to blame for most of the power quality issues. Therefore, it is not uncommon to hear people exclaim, “NEPA!” each time power interruption occurs (NEPA – **N**ational **E**lectric **P**ower **A**uthority is the former Nigerian government monopolistic power company that held sway before the unbundling but notorious for power blackouts, thus consumers nicknamed the acronym “**N**ever **E**xpect **P**ower **A**lways”); even though, on many occasions, the utility’s meters may not indicate any abnormal events on those feeders. It must be realized that there are many events resulting in end – user problems that never show up in the utility’s statistics. Typical examples are momentary faults in the system that may cause voltage sag. In addition, customers overloading a particular line in an unbalanced system can lead to the rupture of the fuse on that line, cutting off power to consumers tied to it. Thus it is often difficult to associate power failure with any particular cause.

4.3 Analysis of Monthly Peak Voltage Logs from the Egbu Sub-transmission Substation

The Egbu 132kV sub-transmission substation supplies six feeders: Umuahia, Airport, Owerri, Oguta, Orlu, and Okigwe, each rated 33kV. In line with one of the purposes of this work which is to investigate, statistically, the power quality issues in the S –E Nigeria, monthly peak voltages on each of the feeders were plotted against time (in month) for one year, using MATLAB 7.0 software. The results are shown below.

4.3.1. Umuahia Feeder

From Fig.5, it can be seen that Umuahia feeder experienced under voltage a good number of months in 2012. In February, the peak voltage recorded was 31kV. In April, October, November and December, the peak voltages recorded were 30kV, 30kV, 30kV, and 30.5kV, respectively. This means that acceptable voltage levels were recorded on the feeder only in seven out of the twelve months of the year 2012, representing about 41.6% of the time. Furthermore, it would be observed from the graph that the under voltages occurred most during the last three months of the year when economic activities are usually at their peaks. In order to compete in business during this period, business owners resorted to the use of generators with the resultant increase in the cost of production. In the end, this increased cost is borne by the consumers.

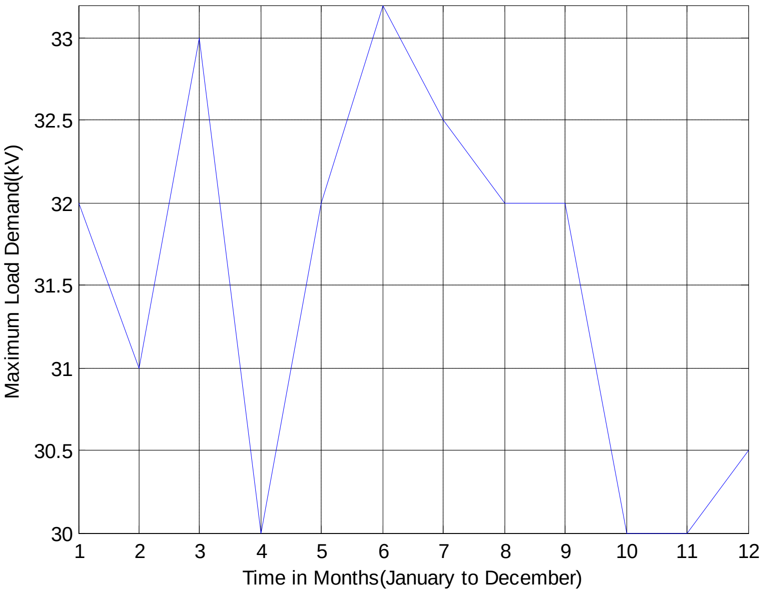

Fig. 5: peak voltage versus time (in month) on Umuahia feeder from Jan. to Dec., 2012.

4.3.2 Airport Feeder

As shown in Fig. 6, in the same year 2012, Owerri Airport feeder recorded under voltages in January, 31kV, and November 31kV which represents 16.6% of the year. Therefore, the peak voltage recorded on Airport Feeder was within the acceptable range only about 83.3% of the time. Although this is relatively good, yet for an industry with such sensitivity as the aviation industry nothing short of 100% quality service the year round is acceptable. Again, November is a very busy month in the South – East Nigeria and the rest of the world when aviation activities near their peak. As unhealthy signal cannot power aviation equipment at the control tower effectively, operators may recourse to self-generation and this as usual puts air travelers at the receiving end.

4.3.3 Owerri Feeder

From Fig. 7, Owerri 33kV feeder recorded ideal signals in February, April, July, November and December. This was encouraging. However, it was operated at 31kV in January and May representing 6.06% deviation from ideal and about 1.06% deviation from the minimum permissible. Even at 31.5kV in March, June, August and October, representing about 4.5% deviation from ideal, though this is within acceptable limits, the feeder did not fare quite well as operating a piece of equipment near its minimum (or maximum) for a protracted period is not advisable. This is not good for small and medium scale enterprises around the Owerri metropolis, especially those sprouting up at Naze, a town in Imo state.

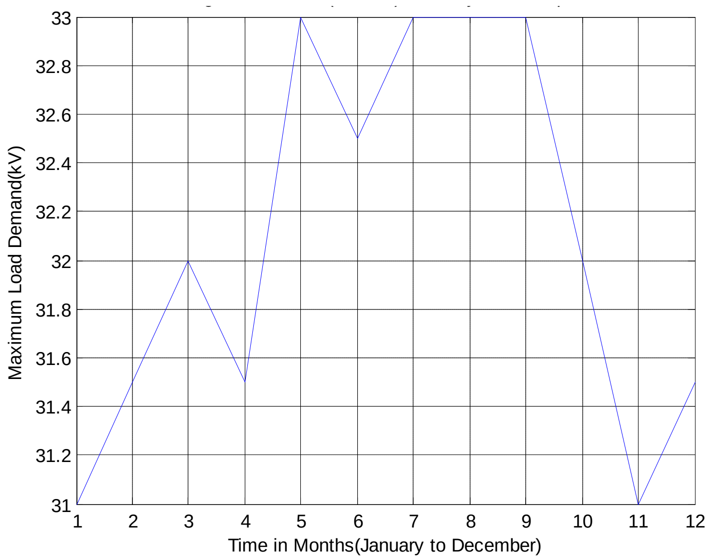

Fig. 6: Peak voltage versus time (in months) on Owerri Airport feeder from Jan. to Dec., 2012.

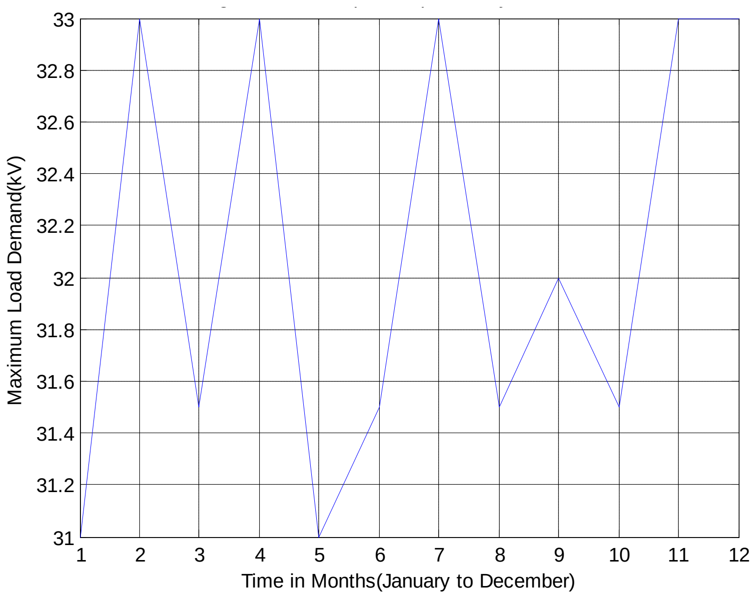

Fig.7: peak voltage versus time (in months) on Owerri feeder from Jan. to Dec., 2012.

4.3.4 Oguta Feeder

From Fig. 8, it can be seen that Oguta line recorded the only incident of undervoltage of 31kV in June, 2012. In February, March, May and September, however, the feeder was operated at 31.5kV representing about 4.5% away from the ideal of 33kV. This means that the feeder was operated at below or almost below acceptable minimum for a total of almost half of the year, with the only ideal voltage recorded in October.

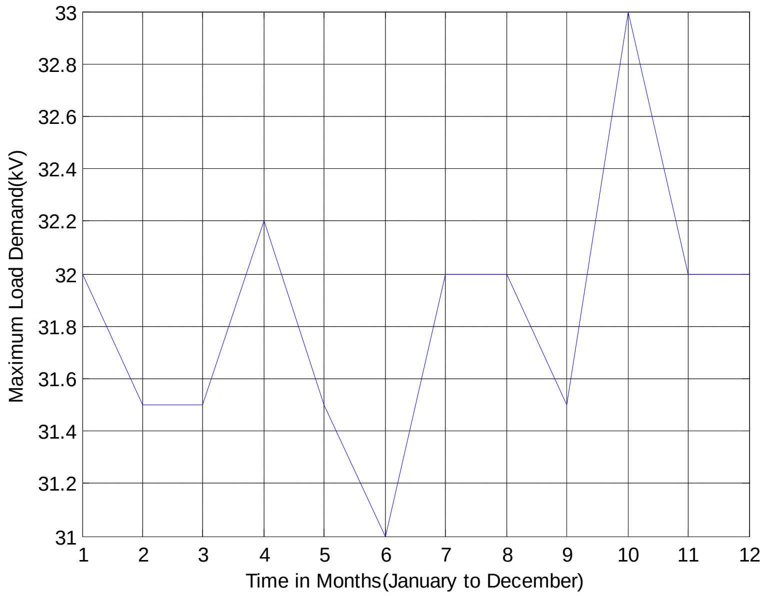

Fig.8: peak voltage versus time (in months) on Oguta feeder from Jan. to Dec., 2012.

4.3.5 Orlu Feeder

In April, October and November power was shipped along Orlu feeder at 31kV, 31kV and 30.5kV, respectively as shown in Fig. 9, which is 1.06% below minimum in April and October, and 7.57% below ideal voltage and about 2.57% below the minimum permissible voltage of 31.35kV in November. However ideal signal levels of 33kV were recorded in June and August the same year.

4.3.6 Okigwe Feeder

And lastly for the Egbu substation, the voltage – time curve for Okigwe feeder is given in Fig.10.
From the graph in Fig. 10, it can be seen that Okigwe feeder recorded only one incident of under voltage of 31kV in September. The feeder however, was operated at near minimum at 31.5kV in February, June, October and November, 2012. With 31.5kV being only 0.48% shy of the minimum permissible voltage of 31.35kV on the 33kV feeder, it is definitely not good enough. This is because operating equipment near their minimum (or maximum) capacity compromises their longevity.

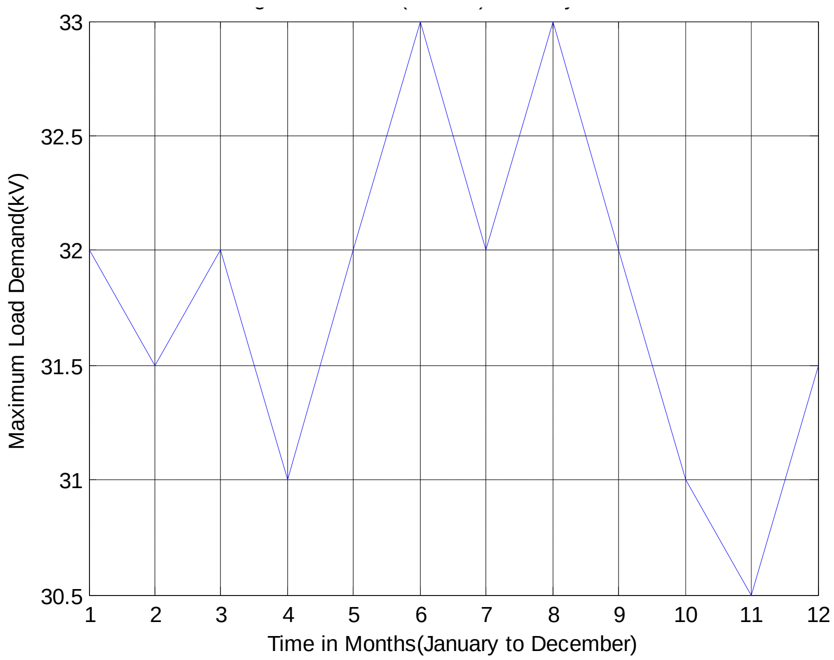

Fig.9: peak voltage versus time (in months) on Orlu feeder from Jan. to Dec., 2012.

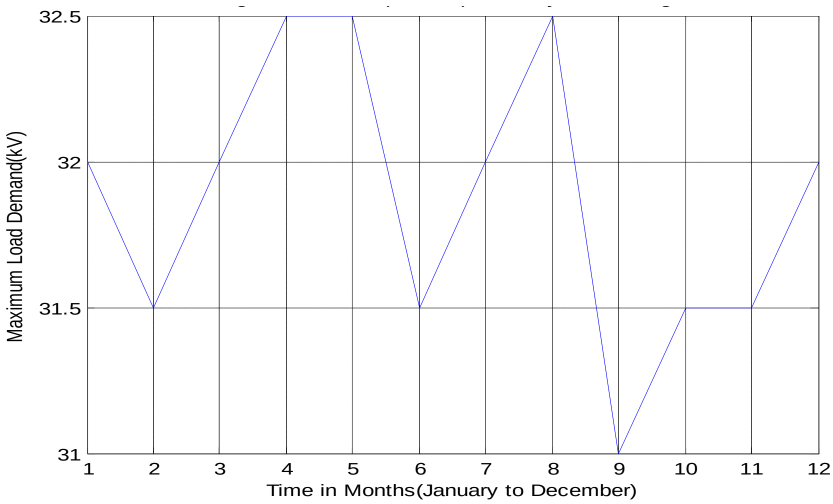

Fig. 10: peak voltage versus time (in month) on Okigwe feeder from Jan. to Dec., 2012.

IV. CONCLUSION

One of the power utility companies' responsibilities is to deliver power to customers at voltage levels within acceptable limits. Improper voltage regulation can cause many problems for end – use equipment. Sustained under – voltages or over – voltages can cause loss of efficiency in electric machines and electronic equipment used at home and in the office; voltage sags can cause nuisance tripping which can lead to shutting down of adjustable speed drives and voltage swell causes data loss, flickering of electric light and damage to equipment. As shown in Figs. 3 and 4, the utility companies and their customers trade blames with each other concerning the origin of poor power quality. While 39% of customers interviewed blamed the utility, 33% of the utility staff blame power consumers. However, from the graphs and analysis of Figs. 5to10, it can be seen that quality power supply has eluded power consumers and this is taking its toll on small and medium scale businesses.

To ameliorate this anomaly, it is recommended that the government increased generation capacity, infrastructural development, and harness renewable energy sources like solar and wind energy. Thesewill go a long way to improving the quality of service delivered to electricity consumers.

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