Power Quality Improvement for Residential Customers of Distribution Network Through Monitoring

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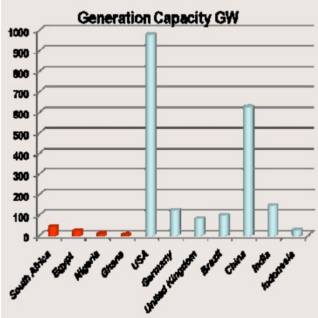
***Abstract*—In today's technologically advanced world, modern man depends so much upon continuous supply of electrical energy. The major world economies demand not only sufficient quantity but equally clean power for continued functioning of a wide array of appliances and equipment for everyday safety, security, mobility and economic welfare. Improving the quality and reliability of electricity power supply has been a major factor behind deregulation and electricity reforms globally. In Nigeria, the debilitating effects of instability in the power sector on the socioeconomic lives of the people left much to be desired. Presently in Nigeria, perhaps due to inadequate power supply; not much emphasis has been laid on monitoring particularly in distribution network. The need for power monitoring as a tool for improving the quality has been emphasized in literatures. The paper presents power quality survey carried out in residential areas of distribution network using Power analyzer equipment. Various power quality parameters were monitored continuously as they were logged in for every ten seconds. The data obtained were then analyzed. Results show that the quality of power measured was below the international standard. Voltage values around 90V were continuously logged in for some periods in part of the network monitored. The result of this survey can help to contribute to industry standards development relating to power quality and effective performance assessment of Distribution Company. It can equally help to establish a more effective communication between the customer and the electrical utility.**

Keywords—Power Quality, Distribution Network, Monitoring

I. INTRODUCTION

Two major issues in power industries are reliability and power quality. While reliability involves sufficient quantity available; power quality is about its 'cleanliness' or 'pureness'. Reliability has been addressed to some extent in some parts of the world especially the developed world. Nigeria as a nation is still facing acute shortage of power to meet the 'burdened' economy and teeming population. With peak generation so far hovering around 5,000 MW in a population of about 170 million implies poor reliability of power supply. Fig. 1 shows the generation capacity of Nigeria in comparison with some selected countries where the Watt per capital is the lowest among the group. The target of at least 1GW of electricity generation and consumption for every one million head of population is set a rule of thumb for any developed industrial nation [4].



Country *	Capacity GW	Watts per capita
S. Africa	40.498	826
Egypt	20.46	259
Nigeria	5.96	40
Ghana	1.49	62
USA	977.06	3,180
Germany	120.83	1,468
UK	80.42	1,316
Brazil	96-64	486
China	623.56	466
India	143.77	124
Indonesia	24.62	102

Fig. 1. Generation Capacity of Nigeria in relation to some selected countries [2]

II. POWER QUALITY

A. Power Quality Globally

Reliability indices are no longer sufficient yardstick in the power industries. The quality of the power is becoming predominant factor especially as the concept of "Smart Grid" to shape future electricity industries is on the horizon globally. Power Quality is the term used to refer to the degree to which a power network is free from power problems. Ranging from transient voltage supply problem to supply outage in the network, PQ captures the total effects of malfunctioning involved. In any modern power network, the supply must be addressed qualitatively and not only quantitatively.

B. Power Quality Monitoring

The Power quality monitoring is one of the major ways to address power quality issues globally. It is necessary to characterize electromagnetic phenomena at a particular location on an electric power circuit as it gives all necessary information about significant power quality disturbances over a long period, varying from weeks to months [13]**.** It also establishes the level or degree of quality and also provides solution to load management at residential/commercial which can help the stakeholders in the power industry in developing standard on PQ. The need to monitor power so as to help track and investigate various power quality for maintaining a high level of power quality and resolve issues before a problem develops or measurement verification of contract has been emphasized [16]. [8] discussed an assessment of power quality and electricity Consumer's rights in restructured electricity market in Turkey. [15] reported a power quality survey of nine electricity distributors was undertaken in 2000/2001 at Australia. [6] reported survey carried out in California using I-Grid system. [1] reported that power quality survey started in Venezuela in 1999. Report of such survey is not common in Nigeria **[**12].

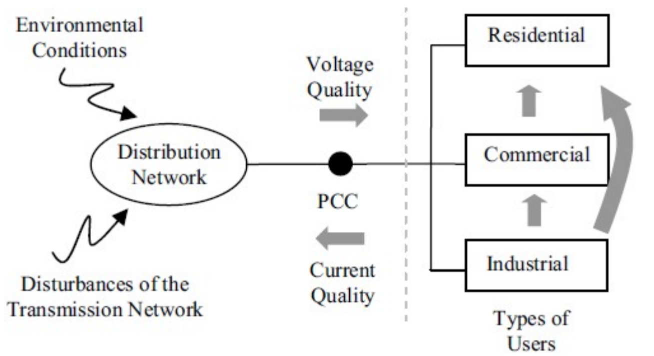


Fig. 2 Shows the need for power quality in distribution network [1]

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C. *OBJECTIVE OF POWER QUALITY MONITORING*

There are various objectives for power quality monitoring. Objectives of monitoring in public distribution include:

i) performance analysis and bench-marking

ii) site characterization

iii) compliance verification

iv) troubleshooting

v) advanced application and studies

vi) active PQ management.

Ensuring power quality involves both Utilities and customers. The objectives can focus on any of the aforementioned. [13] classified and highlighted the objective of PQ monitoring as:

A. System monitoring:

Its aim is to determine the global quality of power and the behavior of the electrical system. For example, to ensure that all bus voltages are within the legal range and that the number of sags is below the maximum permissible tolerance.

B. Local monitoring:

It can be useful to determine whether the utility is providing power at the contracted level of quality, determine whether the cause of electrical disruptions is internal or external, improve power quality service, and so on.

III. POWER QUALITY ISSUE

A. Power Quality Issue in Nigeria

Power quality monitoring is inevitable in a "digitalised economy" which has characterized the 21st century economy as they require clean power for optimum performance. Presently in Nigeria, perhaps due to inadequate power supply; not much emphasis has been laid on monitoring. Electricity as a product is expected to meet the minimum specification. One of the major problems bedeviling Nigerian power industries with its monopolistic market is insensitivity to customer's needs or expectation. Like the proverbial beggar which has no choice, the customer is left with no option than to accept whatever is available. Unfortunately the regulator seems to be helpless. Many a time, the quality of supply is undermined, with no means of seeking redress by the customers. Such expression like "low current" and "half current" are used by end-user to express poor quality of power. Unfortunately, no measure has been taken to determine the value of the poor quality in concrete time.

Generally, quality of power at consumers' end or at point of common coupling is very important as it determines the performance of the appliances. There is room for deviation within specified tolerance range. A common law is that technical performance deteriorates from generator to consumer of electricity [9].

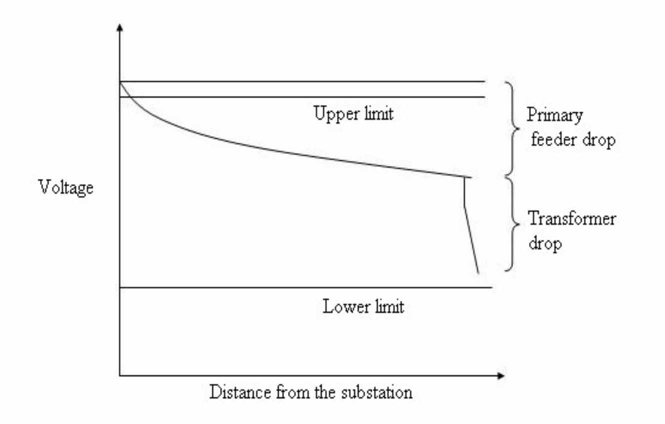

Fig. 3: Example of Voltage profile on a Distribution network [10]

B. Standard Governing Public Distribution Network

There are many existing standards on power quality globally. The common relevant ones are European Norm (EN 50160) and IEEE 519-1992 standards. The EN 50160 standard was developed to cater for the operation of user equipment. Table 1 shows the requirement of EN 50160 on voltage characteristic of distribution network.

IEEE Std. 519-1992 is a standard developed for utility companies and their customers in order to limit harmonic content and provide users with better power quality.

Table I: European Norm 50160:2001 Standard

Parameter	Limits
Frequency	Must remain between 49.5(-1%) and 50.5 (+1%)Hz
Voltage	The voltage must be between 90% and 110% of nominal Voltage.
Voltage Unbalance	The negative sequence cannot assume magnitude higher than 2% of the direct sequence.
Harmonic Voltage	THD <8%

IV. METHODOLOGY

Monitoring of power supply could be done with simple instruments such as multimeter for measurement of voltage, current, frequency as a snap-shot. However, for more accurate and ease of measurement, logging of those parameters over sometime is best suited for this purpose.

In this work, the logging of power quality parameters was done using power and harmonic analyzer. The measurement of the power supply was carried out in residential buildings at Karu area of Federal Capital Territory in Abuja to determine the quality of the supply to a customer for compliance verification [13]. The buildings are located at about 300m from the 500 kVA feeder transformer supplying many buildings mostly residential and few commercial buildings of about two hundred and fifty in numbers. Power supply in the area was generally perceived to be poor. There is therefore need to verify the quality of the power. The PQ parameters focused on this study are voltage level, current level, frequency; crest factor (CF), total harmonic distortion (THD) and dip. The meter used for this work is power and harmonic analyser (DW 6050). It can measured and analyze other several power parameters such as power (real, apparent and reactive), unbalance etc.The use of handheld power quality analyzers which are often fairly lightweight for measurement and record for the purpose of analysis is a common practice. Series of readings were taken at interval. The logged data is then transfer to computer for the purpose of analysis. They are then compared with standard for compliance verification.

V. RESULTS

Statistical analysis was used to analyse the data obtained. The summary data was presented in the form of line and bar-graphs to display the parameters. Analyses of data done in excel to determine minimum, average and maximum, values is shown in Table 2.

The plots of the parameters (voltage, current, frequency, total harmonic distortion and power factor) for the 1st reading are shown in Fig.4 to 8. Fig.9 shows the screen shot from the analyzer. Fig. 10 and Fig. 11 show the voltage and frequency plot for one minute (60s) duration. This is necessary to provide more insight to the clustered values in the general plot. Fig.12 to Fig. 13 show the plots for the 3rd reading with lowest voltage value while Fig. 14 shows the values of dip recorded by the analyzer and displayed in excel format.

Table II: Summary of the data

	1st Reading		*2nd Reading*		*3rd Reading*	
	Voltage (V)	*Frequency (Hz)*	*Voltage (V)*	*Frequency (Hz)*	*Voltage (V)*	*Frequency (Hz)*
Minimum	*183.1V*	*49Hz*	*177.9V*	*49.4Hz*	*83.4V*	*49.4Hz*
Average	*192.6V*	*50.0Hz*	*181.5V*	*50.1Hz*	*90.9V*	*50.1Hz*
Maximum	*199.7V*	*51.1Hz*	*184.5V*	*50.7Hz*	*97.6V*	*50.7Hz*

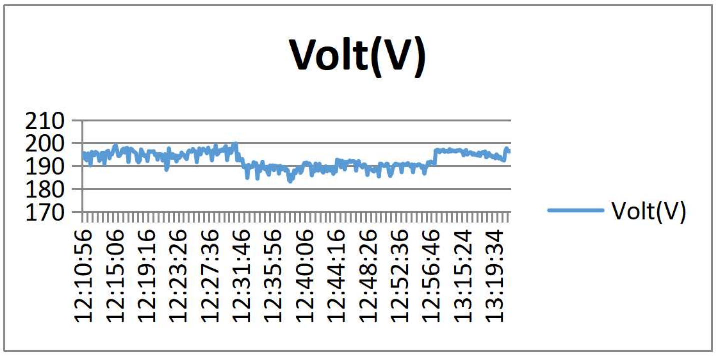

Fig.4: Voltage characteristics

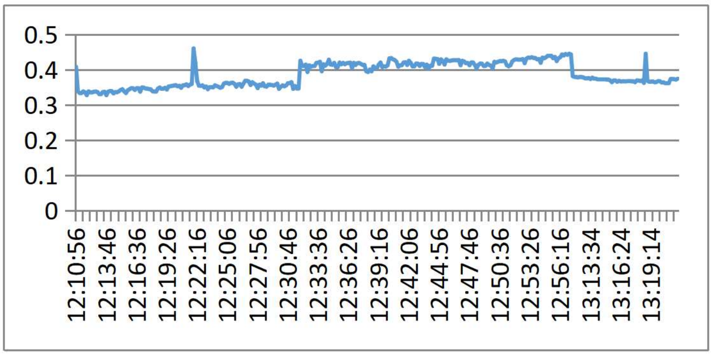

Fig.5: Current characteristics

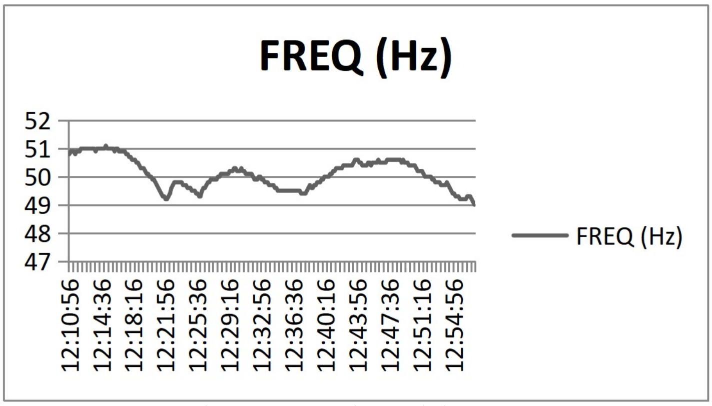

Fig.6: Frequency characteristics

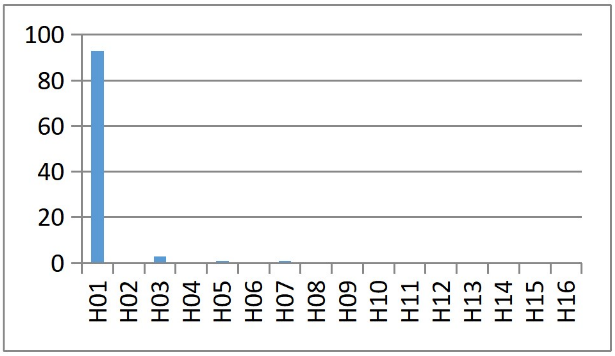

Fig.7: Total Harmonic Distortion

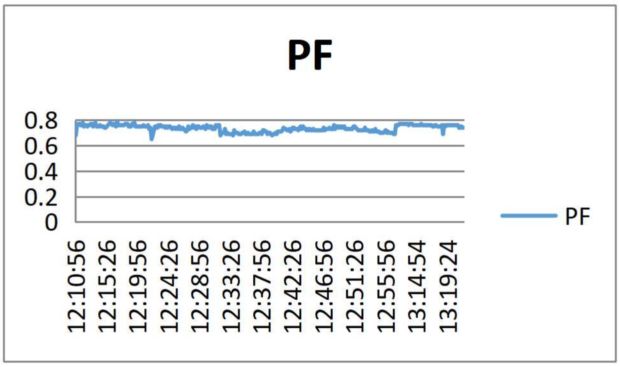

Fig.8: Power Factor


Fig.9: Analyzer screenshot

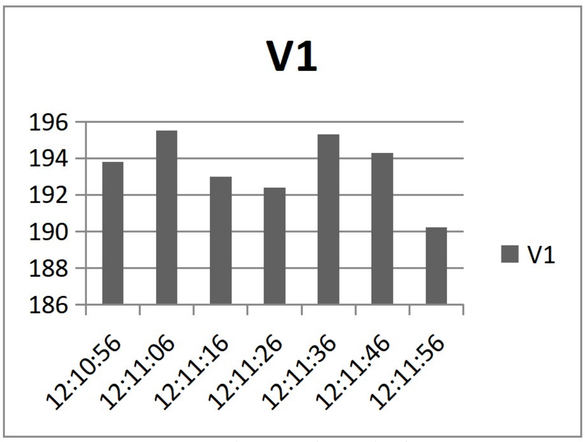

Fig.10: Voltage plot for 60s

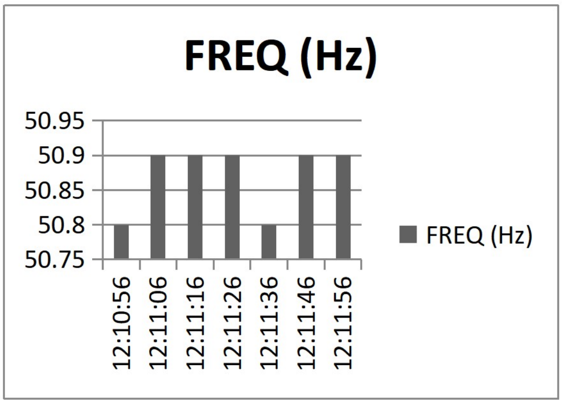

Fig.11: Frequency plot for 60s

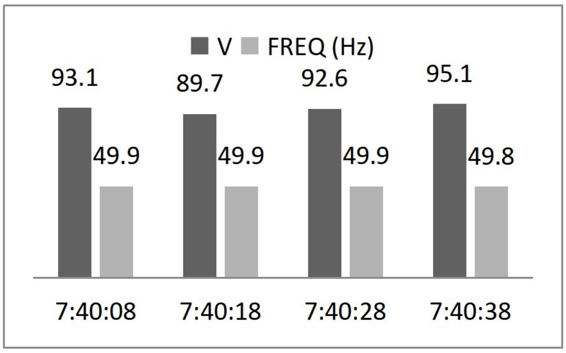

Fig.12: Voltage and Frequency plot for 60s

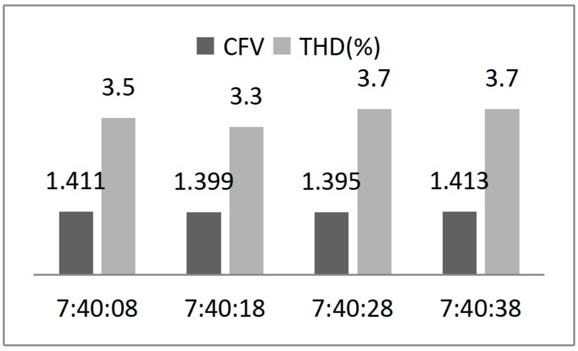

Fig.13: CFV and THD plot for 60s

Table III: Voltage Dip measurement as recorded by analyzer

Date	**VOLTAGE DIP MEASUREMENT**		
	Time	***Line***	***Status***
12/15/2020	19:55:05	V1	DIP
12/15/2020	20:15:04	V1	DIP
12/15/2020	20:34:03	V1	DIP
12/15/2020	20:36:01	V1	DIP-OUTAGE
12/15/2020	20:62:08	V1	DIP
12/15/2020	21:04:1	V1	DIP
12/15/2020	21:40:30	V1	DIP

VI. DISCUSSION

The results show typical characteristic of power quality parameters in Nigeria. The voltage and frequency at domestic level of a single phase supply are 230V and 50 Hz with tolerance of 10% and 1% respectively. From the measured values, the highest value of 199.7V is below the minimum standard of 207V. The worst case is the minimum value of 83.4V. In the case of the frequency, the minimum value of 49.0Hz is below the 49.5Hz and the highest value (51.1Hz) is higher than the standard as well. The total harmonic distortion (THD) of 3.7% as the highest is within the range. A voltage dip which is a short-term reduction in, or complete loss of, RMS voltage occurred seven times within a period less than two hours. A voltage dip means that the required energy is not being delivered to the load and this can have serious consequences depending on the type of load involved. Table 3 shows the compliant evaluation.

Table III: Comparison with Standard

S/N	Power Quality Indices	Standard (EN 50160)	Measured values (min-max)	Compliance
1	Voltage (V)	90% and 110% of nominal 230 207-253	83.4-199.7	No
2	Frequency (Hz)	-1% and +1% of nominal 50Hz 49.5-50.5	49.0-51.1	No
3	THD (%)	THD <8%	3.5-3.7	Yes
4	Dip /Sag		7	No

Thus equipment and appliances in this network are seriously subjected to different conditions beyond their specifications. The implication of this is that economic loss due to this poor quality of power is enormous. While there are mitigating equipment such as uninterruptible power supply (UPS), automatic voltage regulator (stabilizer), surge arrester etc; most of these devices themselves are not design to operate in such harsh environment as this. They are non-linear devices who are not only victim of poor power quality but also contributing to poor quality as well.

VII. CONCLUSION

To ensure good power quality at distribution network, a holistic approach is required. This is because many of the modern equipment are becoming more sensitive to quality of power. This paper provides information on power quality parameters typical of Nigerian power system. This is then compared with standard. The results show that the quality is below the standard. This survey confirmed the poor state of power supply and plight of customer in power industries as to what quality of service obtainable from the service provider. The end-users who are the consumers deserve quality power whenever available. Electricity consumers' right should be strengthened and not trampled upon for healthy electricity market. Strong legislation is necessary to ensure contractual agreement between the producers and consumers is respected.

Power quality survey is an indispensable tool in establishing a more effective communication between the customer and the Electric Utility [1] and therefore should be properly explored locally. When a customer knows he can contribute to power problem directly and indirectly, such a customer will seek for better way to avoid such and thus have healthy relationship with utility.

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