American Journal of Engineering Research (AJER)
e-ISSN: 2320-0847 p-ISSN : 2320-0936
Volume-5, Issue-12, pp-276-281
www.ajer.org
Research Paper Open Access

Analysis of Power Quality in ICT Environment

Ogunyemi, Joel
(Department of Electrical /Electronic Engineering, The Federal Polytechnic Ilaro, Nigeria)

ABSTRACT: *Electricity which is generated and distributed at specified parameters for equipment and appliances to function effectively should be treated as a product which requires quality assurance. Any deviation from the specifications constitutes power quality problems. This study aims at evaluating quality assurance of electrical power by assessing the compliance with two international standards- IEEE 519-1992 and European Norm 50160. The parameters under focus are Voltage, Current, Frequency and Total Harmonic Distortion (THD). Measurements were carried out at the ICT centre of The Federal Polytechnic Ilaro for a week period with a Power & Harmonic Analyzer and the results were statistically analyzed. The results shows that the two international standards (IEEE 519-1992 and European Norm 50160) on current harmonic limit were trespassed implying that quality of power has been degraded. Measures such as derating and use of K-rated transformer to mitigate the problems were recommended.*

Keywords: *Point of common coupling (PCC), Power quality (PQ), Total harmonic distortion (THD).*

I. INTRODUCTION

Continuous power supply at the required quality remains a critical challenge for modern day sensitive electronics and microprocessor controlled devices. Electricity which is the most widely used energy commodity in services is a very unique product produced and consumed instantaneously with little or no room for storage. It is expected to meet the required standard for fairness in an ideal situation. Voltage variation, harmonics distortion and other power quality problems are said to be subjecting equipment in the distribution network to conditions for which they are not designed for with possibility of affecting the system adversely. Since the quality of electrical power at the point of common coupling (PCC) has become an important feature of consumer goods on the market, there is a growing interest in finding, describing and above all, in forecasting system behaviour. With the extensive use of power electronic loads, especially in distribution network which affects proper system operation thus demanding an analytical method to prevent and predict power quality problems. The effects of non-linear load leading to reduction of the system performance and efficiency with destructive tendency on the other nearby loads are undesirable [1]. Another concern in some of the developing countries is the substitution of poor public electricity supply with highly polluting self-generated power [2]. Understanding power system vulnerabilities and developing methods to mitigate or reduce them is therefore in the national interest especially with clamour for "smart grid" as future grid.

The perfect voltage (v) and current (i)are respectively expressed as:

$$v(t) = V_m \mathrm{Cos}(\omega t) ------------------------(1)$$

$$i(t) = I_m \mathrm{Cos}(\omega t - \varphi) ----------------------(2)$$

Where V_m and I_m are the maximum values of voltage and current respectively and φ represent the delay angle.
Power which is the product of voltage and current can be expressed as:

$$p(t) = V_m I_m \mathrm{Cos}(\omega t)\,\mathrm{Cos}(\omega t - \varphi) ----------------(3)$$

However, the presence of disturbances such as harmonic distorts the quality of power in the system. Most of these are emanating from non-linear devices which are increasingly used to combat energy crisis and environmental issue [3] [4]. Hence most of the researches on PQ presently focus on where there are large concentrations of those devices such as data centre or University environment [5].Tracking changes in power quality statistics can provide early indicators of failure in the system. For instance, the transformers used in public distribution network are serving all linear and non-linear loads. Transformer parasitic heating due to harmonic currents is frequency dependent, i.e., higher frequency harmonic currents cause a higher degree of transformer heating and failure. Each harmonic voltage V_{hn} is given by

$$V_{hn} = I_{hn} Z_n \text{ --------------------------------- } (4)$$

Where I_{hn} is harmonic current and Z_n is harmonic impedance.

Total harmonic distortion is a measure of pollution in the system. The total harmonic distortion for voltage THVD is given as:

$$THVD = \frac{\sqrt{\sum_{n=2}^{\infty} V_n^2}}{V_1} \text{ -- } (5)$$

Where V_1 and V_n are fundamental voltage and voltage at the harmonic point respectively.
Similarly, that of the harmonic current is given as:

$$THID = \frac{\sqrt{\sum_{n=2}^{\infty} I_n^2}}{I_1} \text{ -- } (6)$$

Where I_1 and I_n are fundamental and harmonic currents respectively.

Benchmarking among similar facilities can also make significant differences clear and lead to overall performance improvement.The Council of European Energy Regulators (CEER) periodically surveys and analyses the quality of electricity supply in its member countries [6]. The use of statistical analysis for power quality abounds in literatures [7][8] [9]. Statistics on power quality events at PCC are important from the customer's viewpoint. 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. Some of the key areas of the standard are detailed in the following tables 1-4.

Table 1: Voltage Distortion limit

Bus Voltage at PCC	Individual Voltage Distortion	Total Voltage Distortion
69KV and below	3.0%	5.0%
69.001KV -161KV	1.5%	2.5%
161.001 KV and above	1.0%	1.5%

Source [10]

Table 2: Maximum Harmonic Current Distortion (%) of I_L Individual Harmonic Order [Odd Harmonics]

I_{sc}/I_L Ratio	<11	11≤h<17	17≤h<23	23≤h<35	35≤h	TDD-I limit
<20	4.0	2.0	1.5	0.6	0.3	5%
20<50	7.0	3.5	2.5	1.0	0.5	8%
50<100	10.0	4.5	4.0	1.5	0.7	12%
100<1000	12.0	5.5	5.0	2.0	1.0	15%
1000 up	15.0	7.0	6.0	2.5	1.4	20%

Source [10]

Where; I_{sc} = maximum short-circuit current at PCC; I_L = Maximum demand load current (fundamental frequency component) at PCC.
All power generation equipment is limited to these values of current distortion, regardless of actual I_{sc}/I_L

Table 3: Low-Voltage System Classification and Distortion Limits

	Special Application	General System	Dedicated System
Notch Depth	10%	20%	50%
THD(voltage)	3%	5%	10%
Notch Area	16400	22800	36500

Source [10]

Table 4: 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%

Source [11]

II. EXPERIMENTAL PROCEDURE

Measurement was carried out at the Information, Communication and Technology (ICT) centre popularly called PTDF ICT centre located at the West campus in Federal Polytechnic Ilaro, Ogun State. The PTDF ICT centre is currently isolated from grid. Its power network starts from the 65.7kVA generator which supplies four inverters rated 6kW each. The inverter then supplies the building. This is illustrated in the Fig.1 below.

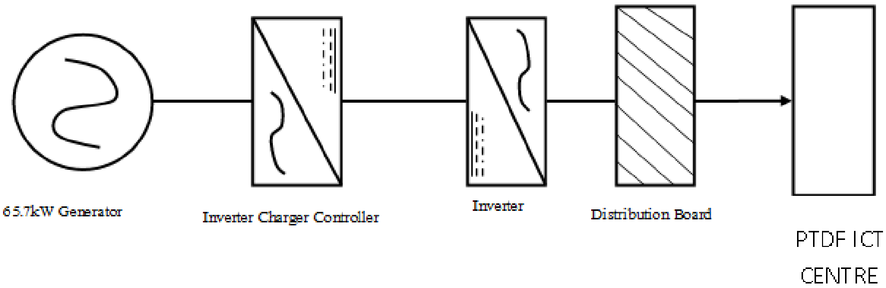

Fig.1. Single line Diagram of area under investigation

The equipment used for the study is Power and harmonic analyser with model DW 6095 (Fig. 2) capable of measuring many electrical parameters with logging facility. It stores measured values in 2GB SD card. For effective readings, measurements were taken at point of common coupling (PCC) as shown in Fig.3.

Fig 2: Power& Harmonic Analyser(DW6095). **Fig. 3:** Connection of probes at PCC

The parameters to be investigated under this study are: i) Voltage variation ii) Current variation iii) Frequency variation and iv) Total Harmonic Distortion (THD). Data were collected and measurements were scheduled for a week between 8:00am to 4:00pm daily during the office hours. At least one week of readings was recommended by the IEEE-519 and EN 50160 standards in order to establish if maximum limit of total harmonic distortion for current and voltage (THID and THVD) must be <8% and 5% respectively for current less than 50A. Data collected during the week was at 10minutes interval rate as required by the standard. The measuring instrument (i.e. Power & Harmonic Analyzer) was programmed to log in at this interval. The IEEE-519 standard stated that the maximum limit of THVD must be <5% and if over must not exceed 1hour. The European standard 50160 says that the THVD should not overpass 8%. Results were summarized in tables and presented in graphical forms. Descriptive statistic such as mean and standard deviation were then used to establish the probability of occurrence of such events

To calculate the probability of the harmonics less than the given percentage, a normal distribution equation was used as follow[7]:

$$Z = \frac{X-\mu}{\sigma} \quad \text{---} (7)$$

Where Z is the probability of less than a given percentage X; μ is the mean and σ is the standard deviation.

III. RESULT AND DISCUSSION

The statistical summary of one week recording of the fundamental voltage measured at the PCC is presented in Tables 6-9.

Table 5: Mean of voltages obtained from Monday-Friday

Voltage	Minimum	Maximum	Mean	Std Dev
V1	214.46	224.48	219.47	1.055923
V2	219.78	230.22	225	2.854378

V3	212.94	223.9	218.42	1.798385

Table 6: Mean of Current from Monday-Friday

Current	Minimum	Maximum	Mean	Std Dev
A1	9.845	11.86	10.85	0.1684
A2	9.865	11.46	10.66	0.3007
A3	11.47	12.04	11.75	0.5398

Table 7: Mean of Real, Apparent and Reactive Power

Day	Real power (kW)	Apparent power (kVA)	Reactive power (kVAR)
Mon	8.89	10.53	5.45
Tue	8.829	10.1	4.86
Wed	7.876	9.234	4.74
Thur.	9.092	10.2	4.6095
Fri	7.295	8.77	4.807

Table 8: THVD Voltage (%)

Day	V1	V2	V3
Mon	2.4	2.4	2.1
Tue	2.3	2.2	2.5
Wed	2.4	2.2	2.2
Thur	2.4	2.1	2.7
Fri	2.3	2.3	2.6

Table 9: THID Current (%)

Day	A1	A2	A3
Mon	15.9	8.4	11.8
Tue	23.2	8.5	7.7
Wed	16.5	6.7	5.7
Thur	18.3	8	8.9
Fri	17.4	14.9	7.1

Table 10: Frequency from Monday-Friday

Day	Frequency (Hz)
Mon	51.02
Tue	51.2
Wed	51.1
Thur	51.054
Fri	51.2

IV. ANALYSIS OF TOTAL HARMONIC DISTORTIONS FOR VOLTAGE AND CURRENT (THVD& THID)

From table6-9; while the phase supply voltage appears to be within the limits, the range of current readings shows a relatively balance loading and power consumption by the load far below the output of both the generators and inverters (more loads can be accommodated in the future) further analysis is necessary not only to establish whether the maximum deviation violated the international standards but for how long in the week period of measurement as well. This is derived from the mean value and standard deviation of voltage and current.

To calculate the probability of the THVD less than 5%

Table 11: Mean and standard deviation of THVD

THVD	Mean	Standard Deviation
V1	2.36	0.2973
V2	2.24	0.6809
V3	2.42	0.6125

At 95% Confidence interval

$$Z = \frac{X - \mu}{\sigma}$$

From the above table of mean and standard deviation of the THVD the highest was 2.42 with 0.6125 standard deviation. For probability of THVD to be <1%

$Z = \frac{1-2.42}{0.6125}$= -3.318
T(Z)= 0.0104 i.e. probability THVD < 1% is 1.04%

For probability of THVD to be < 2%
$Z = \frac{2-2.42}{0.6125}$ = -0.6857
T(Z)= 0.2776 i.e. probability THVD < 2% is 27.8%

For probability of THVD to be < 5%
$Z = \frac{5-2.42}{0.6125}$= 4.25
T(Z)= 0.9999888 i.e. probability THVD < 5% is 100%

Table 12: Probabilities of the THVD less than 5%

THVD	<1%	<2%	<3%	<4%	<5%
Probability	0.0104	0.2776	0.8289	0.99396	0.9999888

Similarly, to calculate the probability of the THID less than 8%

Table 13: Mean and standard deviation of THID

THID	Mean	Standard Deviation
I1	18.26	3.65
I2	9.3	1.52
I3	8.24	2.132

At 95% Confidence interval
$$Z = \frac{X-\mu}{\sigma}$$

From the above table of mean and standard deviation of the THID the highest was 18.26 with standard deviation of 3.65. For probability of THID to be <1%

$Z = \frac{1-18.26}{3.65}$ = -4.73
T(Z)= 0.00000112 i.e. probability THID < 1% is 0.000112%

For probability of THID to be < 2%
$Z = \frac{2-18.26}{3.65}$= -4.46
T(Z)= 0.00000410 i.e. probability THID < 2% is 0.00041%

Table 14: Probabilities of the THID less than 8%

THID	<1%	<2%	<3%	<4%	<5%	<6%	<7%	<8%
Probability	0.000112	0.00041	0.00146	0.00461	0.0142	0.039	0.1	0.248

V. DISCUSSION

The analysis shows that the international limit was not violated for the period under investigation for the voltage. The European standard EN50160 stipulated that the data collected during the one week with sampling rate of 10minutes, 95% of the values should be in the established capability range. The THVD must not overpass 8%. It was established from the above calculations and figures that THVD values measured conforms to the international standards and the limit was not transgressed. However, from the analysis, it could be seen that for the period of one week the probability of achieving THID < 8% is very rare. Also, the lowest frequency recorded was 51.02Hz while the highest frequency recorded was 51.2Hz. This range of frequency shift is above the limit specified by standard which is between -1% to +1% of 50Hz. This implies that the power does not conform to the international standard and thus shows that the system is polluted by the harmonic currents generated by the non-linear devices. The effect of this is that the generator lifespan may be reduced with more of such non-linear device loads. Also, if the centre is eventually connected to the grid, transformer serving the centre may be considered for derating. A 25% derating for transformers and generators is commonly employed in industry. The use of K-rated transformer specifically designed to handle nonlinear loads is another solution. The K factor is basically an index of the transformer's ability to handle nonlinear load current without abnormal heating. The higher the K factor value, the better the transformer's ability to handle nonlinear loads.

VI. CONCLUSION

This work has examined the quality of power supply feeding ICT centre. Results show that while voltage harmonic distortion is within the specified international limit, the current harmonic distortion is not. This implies the quality of power in the system is affected. This may necessitate some measure to forestall degradation of power as more loads are added. One of such is derating of the transformer and the use of K-rated transformer. Sustainable development in power industry can only be achieved if the quality assurance of system components can be ensured.

REFERENCES

[1]. A.J. Onah Harmonics: *Generation and Suppression in AC System Networks. Nigerian Journal of Technology (NIJOTECH), Vol. 31, No. 3, November, 2012, pp. 293-299*.

[2]. A. Iwayemi *Investment in Electricity Generation and Transmission in Nigeria: Issues and Options". Quarterly publication of International Association for Energy Economics. First Quarter. pp 37-42 (2008)*

[3]. M. S. Witherden *The Influence of Non-linear Loads on the Power Quality of the New Zealand Low Voltage Residential Power Distribution Network.M.Sc thesis. Massey University, Manawatu, New Zealand*. (2012).

[4]. J. Ogunyemi, A. Fakolujo and I.A. Adejumobi Power Quality Assessment In Nigerian Distribution Network", *Proceedings of EIE's 2nd International Conference of Computing, Energy, Networking, Robotics & Telecommunication* Nov 21st-23rd. 2012, Covenant University, Ota Nigeria.

[5]. M.H Shwehdi *Harmonics Effect in Industrial and University Environments, Power Quality Harmonics Analysis and Real Measurements Data*Prof. Gregorio Romero (Ed.), ISBN: 978-953-307-335-4, InTech. Available from: http://www.intechopen.com/books/power-quality-harmonics-analysis-and-real-measurementsdata/harmonics-effect-in-industrial-and-university-environments.(2011),

[6]. CEER Benchmarking Report on The Quality of Electricity Supply, 5th edition, 2011.

[7]. A. O. Olatoke, S.S. Sultan and M.K. Darwish. "Statistical Analysis of Power Quality in Office Buildings." International Journal of Scientific & Engineering Research, Volume 3, Issue 12, April-2012 1 ISSN 2229-5518. Available at http://www.ijser.org.

[8]. D. D. Ferreira, C. A. G. Marques, J. M. de Seixas, A.S. Cerqueira, M. V. Ribeiro and C. A. *Duque Exploiting Higher-Order Statistics Information for Power Quality Monitoring Power Quality, Mr Andreas Eberhard (Ed.),* ISBN: 978-953-307-180-0, In Tech, Available from: http://www.intechopen.com/books/power-quality/exploiting-higher-order-statistics-information-for-powerquality-monitoring. (2011).

[9]. A.B Nassif *On the Reliability of Real Measurement Data for Assessing Power Quality Disturbances, Power Quality Harmonics Analysis and Real Measurements Data, Prof. Gregorio Romero (Ed.), ISBN: 978-953-307-335-4, InTech*, Available from: http://www.intechopen.com/books/power-quality-harmonicsanalysis-and-real-measurements-data/on-the-reliability-of-real-measurement-data-for-assessing-powerquality-disturbances. (2011).

[10]. IEEE Standard 519-1992 Harmonic Limits in VDF applications."(1992).

[11]. European Norm 50160 The Revision of European Standard EN 50160 on Voltage characteristics of electricity Supplied by Public Distribution Networks. (2001).