Perspectives On Electric Power Quality Problems: Corollaries And Remedies

Chiejine, Chinedu Michael
Department of Electrical/Electronic Engineering Technology School of Engineering Technology
Delta State Polytechnic Ogwashi-uku,
Delta State, Nigeria
Email: pstchiejine@yahoo.com

***Abstract*—The craving for qualitative electric power supply for industrial and domestic consumers has soared greatly in recent years due to increasing sensitivity of their devices which require high quality electric power supply as well as massive losses incurred as a result of poor power quality. In order to forestall the huge econo-technical losses associated with power quality problems, a balance knowledge of the entire entailment of the subject is de rigueur. The motivation for this paper arises from the shifting needs and constraints faced by electricity consumers (especially the industrial customers) due to the growing appliances of sensitive complexion used for their operations and the connection of more distortion-instigating power electronic devices into the network. Greater responsiveness and apprehension of different categories of customers to losses incurred due to PQ problems and the diverse kind of pressures on the utility companies as a result of the regulations has made this study more of a necessity now than ever. This paper has explored PQ problems and their corollaries, as well as suggested some basic, tried and tested techniques, using interface devices and other prophylactic methods as tendered, with the bated breath that they will proffer satisfactory remedy to this critical worldwide issue.**

***Keywords*—Power Quality; harmonics distortion; nonlinear loads; electricity consumers; sensitive electronic equipment; interface devices.**

I INTRODUCTION

The craving for qualitative electric power supply for industrial and domestic consumers has soared greatly in recent years due to increasing sensitivity of their devices which require high quality electric power supply. Furthermore, with respect to functionality and practicality, electrical contrivances have become more convoluted in regard to their interactions with other appliances connected to the supply network. Just a little upset in the supply voltage could result to an extensive incommode and disruption to the entire operation with consequent huge financial setbacks for the customer. Thus, all electricity consumers, comprising industrial, commercial and domestic consumers anticipate voltage that meet stipulated quality requirements at their point of connections. Nonetheless, Power Quality (PQ) insufficiency-related complaints keeps increasing by the year with the consequent financial and technical encumbrances, both to the customers and utility companies. The principal motivations for this paper arises from the shifting needs and constraints faced by electricity consumers (especially the industrial customers) due to the growing appliances of sensitive complexion used for their operations and the connection of more distortion-instigating power electronic devices into the network. Greater responsiveness and apprehension of different categories of customers to losses incurred due to PQ problems and the diverse kind of pressures on the utility companies as a result of the regulations has made this study more of a necessity now than ever.

Sometimes, PQ problems and disturbances are wrongly solely attributed to power utility companies. Conversely, PQ disturbances may well emanate from both the network provider and the customers alike. When it originates from the customer’s installations, it can spread to other part of the network and taint its entire PQ. Consequently, the obligation of PQ sustainability should be shared by both the utility providers and the different categories of customers.

This paper evaluates electric power supply quality problems, its consequences on customers as well as functional remedial techniques.

II WHAT IS ELECTRIC POWER SUPPLY QUALITY?

Broadly speaking, PQ is the degree of conformance of supply voltage characteristics to the generally acceptable standard. Numerous definitions have been put forward by different standards books. For instance, [1] defined PQ as “the characteristics of electricity at a given point on an electrical system, evaluated against a set of reference technical parameters.” On the other hand, [2] defined PQ as “the concept of powering and grounding sensitive equipment in a manner that is suitable to the operation of that equipment.” This definition however, is somewhat partial because it views PQ as a problem only when gadget and there performance are encumbered. Then again, [3] defined PQ as “any power problem that reveals itself in voltage, current and frequency deviation, which causes the failure or breakdown of a customer's equipment. Moreover, [4] defined PQ as the concept of powering and grounding electronic equipment in a manner that is suitable to the operation of that equipment and compatible with the premise wiring system and other connected equipment. Whichever way one thinks about it, PQ expresses equally the degree of deviation or distortion from pure supply waveform as well as supply steadiness. In other words, any substantial variation in the magnitude, frequency, waveform or equilibrium of line voltage is a probable PQ problem [5].

III CAUSES OF POWER QUALITY POWER

In any electrical supply network, the presence of undesirable components in the power frequency, voltage or current waveforms brings about compromise in its quality. Several factors can influence poor PQ, ranging from weather conditions, asymmetrical loading on distribution transformer phases to the use of convoluted electronic devices by customers. All these, coupled with other factors increase the probability of PQ problem. When the voltage and current components are tainted by any form of undesirables, the ideal waveform is altered. In any power system network, whatever occurrence that initiates any form of deviations from nominal values of supplied voltage, distort the waveform from pure sinusoidal form, or vary the fundamental frequency, certainly impair and interfere with its PQ [6]. Typical examples of such occurrences as stated by [7] are:

- Electrical switching (digital) devices including switch mode power supplies
- Arcing devices including fluorescent lamps and welders
- Deteriorated wiring, connections or ground currents
- Weak, overloaded power supplies
- Saturated (nonlinear) transformers (florescent ballast)
- Various system design problems including transformer saturated from geomagnetically induced current

Electrical distortion is typified by the following characteristics: noise, harmonics, voltage sag and swell, flicker, frequency fluctuations, supply interruptions and so on.

IV PQ PROBLEM AND THEIR COROLLARIES

A. Noise

Sometimes in power systems, some unpredictable and unwanted random signals superimpose on power waveforms. This is referred to as electrical noise. They are characterized by long series of comparatively high-frequency impulses with alternating amplitudes driving on the power waveform. Noise in power system affects equipment operation by making power and control systems less reliable. Typically, noise disturbances can emanate from natural sources in the atmosphere like geomagnetic storms; or operation of certain electrical or electronic devices such as broadcast transmitters, arcing motors and electric welders [7]. Again, occasionally, current flows through conductive paths formed by multiple ground connection. This causes ground loop noise. Under this condition, the current causes ground-connection points of grounded elements to be at different electrical potentials with its vast implications.

B. Harmonics

Harmonics are AC voltage or current that possess waveform cycle at a frequency of an inter-multiple of the fundamental power frequency. For example, a power system with 50Hz fundamental frequency has its second harmonics as 2 x 50 Hz which 100Hz; and its third harmonics as 3 x 50Hz which is 150Hz. There are however, harmonics which are not necessarily integer-multiples of the fundamental frequency. They are called interharmonics. The interplay of harmonics and fundamental frequency results in a single distorted waveform. Harmonics are usually triggered by the use of variable-speed drives, nonlinear electric loads, rectifiers, saturated transformers (fluorescent lighting ballast). Solid state switches, high intensity discharge arc lamps and other nonlinear or arcing devices and frequency converters [8]. [9] noted that nonlinear loads produce harmonics when connected to voltage supply network, and that their impedance vary with supply voltage drawing non-sinusoidal current which eventually create voltage distortion in the network. Thus, any other load linked to the distribution network is affected by the resultant voltage distortion [10, 11]. The overall level of harmonic distortion of a voltage waveform is referred to as Total Harmonic Distortion (THD). The THD of voltage waveform can be evaluated by the relation:

$$V_{THD} = {}^{100x}\sqrt{\frac{\sum V_h^2}{V_I^2}} \quad \text{(i)}$$

where V_{THD} = The THD of a voltage waveform in %,

V_h= The rms voltage for specified sinusoidal harmonic waveform and

V_I = The rms voltage of sinusoidal waveform whose frequency is the fundamental frequency.

Some industrial power systems can record up to 15% THD or more, whereas THD of 5% is enough to cause problem in a system [7].

C. Voltage Variation

In PQ problems, the magnitude of the voltage is always a concern because of possibilities of variations. Voltage variations presents itself in different forms. When the voltage change from the nominal value is within the range of microseconds to some fractions of one minute, it is said to be short duration, in which case they turn out as dip or sag, swell, spike or surge. On the other hand, variations of long duration occur as overvoltage, undervoltage, flickers, and interruptions. In general, voltage variation come about due to faults on the network, restoring power following an interruption, switching of nonlinear loads, loading problems and so on.

C (i) Voltage Dip or Sag

Voltage sag is a diminution in RMS nominal voltage for a short period of time (between half cycle and one minute) to between 0.1 and 0.9 pu in RMS at power frequency. Energizing heavy loads such as large electric motors, wind turbine etc. are typical causes.

C (ii) Voltage Swell

Voltage swell is a rise in RMS value of nominal voltage at power frequency to between 0.1 and 0.9 pu for a duration of half cycle to one minute. Swell occur typically as a result of faulty system conditions at any point of the network, switching off heavy loads, and unbalanced loading in a 3 phase system etc.

C (iii) Flicker

When there is randomized recurrence in voltage variations between 0.9 -1.1 pu in an AC network, flicker is said to have occurred. It results in an impression of instability of the visual sensation produced by a light stimulus whose luminance fluctuates with time. It is irritating to human sight. The cause of flicker is fast switching operations in industrial processes and devices like electric motors, arc furnaces and pulsating loads.

C (iv) Overvoltage

This is an increase in RMS voltage greater than 110 percent at power frequency for duration longer than one minute [12]. Switching off large loads, inadequate voltage control, and line faults are typical causative factors of overvoltage.

C (v) Undervoltage

This is a decrease in RMS value of AC voltage to 90 percent for over one minute duration. Typical causes are turning on large load, line faults and overloading of circuits.

C (vi) Interruption

Interruption is said to have occurred when the supply voltage drops below 0.1pu for a duration of not more than one minute. When the interruption is more than one minute in duration it is said to be a sustained interruption [3]. Insulation failure, failed or improper grounding, lightning control malfunction etc. are some of the common causes of interruption.

C (vii)Outage

Power outage is a short or long-term state of electric power loss in a given area or section of a power grid. It is also known as power failure, or blackout. The common causes are often faults in the power lines and in distribution station themselves [13]

D. Frequency

When there is a change in frequency from the nominal stable utility frequency of 50-60Hz, it is referred to as variation. For sensitive equipment, it may lead to data loss, equipment lock up or program failure. Frequency variation beyond the tolerance limit of $\pm 5\%$ compromises the quality of the power system, and thus, may lead to system collapse [14].

V. CONSEQUENCES OF INADEQUATE PQ AND SOLUTION

Myriads of inconveniences emanate from PQ inadequacy to all categories of customers. Technical and economic damages at their installation form major part of their complaints to utility providers.

A. Technical Consequences of Poor PQ

The customers use varied and huge number of equipment at their installations that encompass various electrically operated converter loads. While the residential customers make use of diverse household appliances such as cookers, boilers, television, microwave ovens, personal computers, heating-ventilation-air conditioning equipment etc. the business and office equipment comprise of Copiers, Computer work Stations, printers, lighting systems, etc. Then again, among the devices used by the industrial customers are computerized numerical control (CNC) tools, Programmable Logic Controller (PLC), Variable Speed Drives (VSD), inverters and so on. These devices are relatively impressionable to PQ problems. The need for high PQ has never been so critical worldwide due to the miniaturization of modern electronic devices which makes them more vulnerable to PQ problem. Power abnormalities and distortion instigate problems like overheating of machinery due to undervoltage, high torsional forces occasioned by overvoltage, mechanical vibration arising from power distortion component frequencies; and the effect of vibration are stronger when the frequency of the distorted waveform of the system matches up with the inherent resonance of the equipment. Furthermore, abnormal voltage can collapse the dielectric strength, and hence electrical insulation thereby leading to short circuiting, overheating and failure. Moreover, PQ problems trigger erratic operation of control, data processing and diagnostic systems and so, can lead to business down time, product rejects and high operating costs [7].

Additionally, outages can result to severe effects such as: computer data loss, solidification of molten metal, deformation or sagging of a shaft on a large, idle rotary machine, runaway reactions for chemical processing plant, failure of protection system and odds of defectiveness of hospital life-support equipment.

VI. PQ IMPROVEMENT TECHNIQUES

Generally, it is imperative to have an all-inclusive inspection of the wiring, grounding and bonding integrity of all installations within the customer's premises. The whole electrical network should be examined for improper connections at the various panels, as well as loose or missing linkages. Checks for improper conditions like reverse polarity, open neutral or detached/floating grounds should be tested with appropriate circuit testers. The panels linking heavy inductive loads, all nonlinear load and any other electrical- noise-engendering equipment like air compressor loads should be isolated from the ones feeding the sensitive electronic loads. Moreover, it should be ensured that ground and neutral conductors are not shared between branch circuits [15].

Furthermore, it should be noted that the quality of the equipment grounding and bonding directly determines the performance of computer based industrial system. In other words, erroneous grounding and bonding set up will give rise to defective system performance. Equipment grounding system also known as "safety ground" functions differently from the neutral (i.e. the grounded conductor). The safety neutral protects the equipment and systems from effects of lightning, surge voltages, accumulation of static charges and creates a "zero-voltage" locus for the system. It is essential that the equipment grounding system maintain low impedance path from the equipment to the node with the grounding electrode at service entrance. Appropriate grounding and bonding reduces unnecessary but costly disturbances [16]

Numerous on hand measures abound in regards to ameliorating PQ problems. Table 1 shows a synopsis of some of the major ones, using appropriate interface devices. .

Table 1: Synopsis of some of the major PQ solution Techniques

S/NO	PQ PROBLEM	SOLUTION TECHNIQUE
1	Noise	Application of noise filters: To reduce noise, various options are available such as breaking up ground connection paths and correcting ground connections. In case of powerline noise, "noise" or "low pass" filters can be installed, in which case only power waveforms at the desired frequency of 50 or 60hz are allowed to pass through the filters while transient (and undesired) waveforms cannot.
2	Unwanted harmonics	To minimalize or regulate the effects of harmonics on equipment and systems, harmonic filters are employed to curtail harmonics and keep the THD less than 5%. There are many types of filters in this regard namely: active harmonic filters, passive harmonic filters, line reactors, electronic feedback filters and special transformers that engage out-of-phase windings to achieve harmonic attenuation [17].
3	Transient voltage surge	The use of Transient Voltage Surge Suppressor (TVSS).They are used to interface between the power source and sensitive loads, so that the transient voltage is clamped before it reaches the load
4	Transient noise emanating from mains	Isolation transformers are used to reduce common mode noise; although they cannot compensate for voltage fluctuations and outages
5.	Voltage variations	Voltage regulators are typically installed where there is fluctuations in input voltage but total loss of power is unusual [17]
6	Outage	Uninterrupted power Supply (UPS) is applied, and most applicable when down time ensuing from outage is intolerable. This can forestall computer data loss, and also invaluable in application like hospital life support equipment etc.

VII. CONCLUSION

The availability of quality power supply is critical in modern day society. Therefore, in order to forestall the huge econo-technical losses associated with PQ problems, it behooves the customers, especially the industrial and commercial ones to take appropriate proactive steps to prevent losses, which are sometimes enormous, that may arise as a result of PQ problems in their facilities. This paper has explored PQ problems and their corollaries, as well as suggested some basic, tried and tested techniques, using interface devices; other prophylactic methods have also been tendered, with the bated breath that they will proffer satisfactory remedy to this critical worldwide issue.

REFERENCES

[1] IEC 61000-4-30 (2008.) "Testing and measurement techniques – Power quality measurement methods (Edition 2.0): Published by International Electrotechnical Commission,

[2] IEC 61000-3-7 (2001.) "Assessment of emission limits for fluctuating loads in MV and HV power systems", IEC, Geneva, Switzerland,

[3] Dungan, R; McGranagham, M; Santoto, A and Beaty, H (2012) Electrical Power System Quality, 3rd edition, McGraw-Hill, New York

[4] IEEE 100 (2000) The Authoritative Dictionary of IEEE Standard Terms, seventh edition pp234

[5] Forum of Regulators (2018) Report on Power Quality of Electricity Supply to Consumers http://www.forumofregulators.gov.in/Data/Reports/Power07.pdf. Accessed 5th march 2019

[6] John, D. O; Hassan, K. A (2016) Issues of Power Quality in Electrical Systems. International Journal of Energy and Power Engineering. 5(4) pp 148-154. http://www.sciencepublishinggroup.com/j/ijepe. Accessed 2nd February, 2019

[7] GAP.5.7.1.3 (2015) Electric Power Quality and Reliability GAPS Guidelines A Publication of Global Asset Protection Services LLC. https://axaxl.com/-/media/gaps/5713___0.pdf. Accessed 1st April, 2019

[8]Mindykowski, J (2014) Power Quality on Ships: Today and tomorrow's Challenges. International Conference and Exposition on Electrical and Power Engineering (EPE 2014), 16 -18 October, Lasi, Romani

[9] Ahmed, I. A; Zobaa, A. F and Taylor, G. A (2015) Power Quality Issues of 3MW Direct –Driven PMSG Wind Turbine. 50th International Universities Power Engineering Conference (UPEC), Sept. 2015

[10] What are non-linear loads and why are they a concern today? Available at http://www.mirusinternational.com/downloads/hmt_faq01.pdf. Accessed 28th March, 2019.

[11] Gazafrudi, R. S; Langerudy, A; Fuchs, E and Al-Haddad, K (2015) Power Quality Issues in Railway Electrification: A Comprehensive Perspective IEEE Transactions on Industrial Electronics, 62(5) May, 2015

[12] Sonia, Pinkey and Naveen Kumar (2014) Power Quality Disturbances and Improving Power System Reliability, International Journal of Computer Science and Mobile Computing, Vol.3 Issue.8, August- 2014, pg. 760-768

[13] Techopedia. What does *Power Outage* mean? Available online

https://www.techopedia.com/definition/13085/power-outage. Accessed 8th April 2019

[14] http://www.power-solutions.com/power-quality. Accessed 8th April 2019

[15] Suzette, (2006) "Total Power Quality Solution Approach for Industrial Electrical Reliability", August 2006 issue of Power Quality World.

[16] Rojin, R.K (2013) A Review of Power Quality Problems and Solutions in Electrical Power System International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering Vol. 2, Issue 11, November 2013

[17] Agarwal, A; Kumar, S; and Ali, S (2012) A Research Review of Power Quality Problems in Electrical Power System MIT International Journal of Electrical and Instrumentation Engineering, Vol. 2, No. 2, Aug. 2012, pp. (88-93)

[18] Arrillaga, J., Watson N.R. and Chen, S.(2000) Power system quality assessment, John Wiley and Sons, 2000.