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Poor Power Quality in Nigerian Power Systems: Causes and Remedies

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Abstract
This paper presents poor power quality in Nigerian power systems: causes and remedies. Poor power quality is analyzed from the view point of a power engineer and this is followed by an enumeration of some issues that cause poor power quality in electricity grid. Factors such as overloading of distribution networks, poor maintenance culture, harmonic distortion from non-linear loads, poor power generation and supply imbalance, etc are discussed. Solutions are proffered based on empirical evidence and technicalities.

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I. Introduction

Electric power quality refers to the ability of the electrical power system to supply consumers with voltage and frequency that remain within acceptable limits for the proper operation of electrical equipment. In Nigeria, poor power quality has become a major challenge affecting residential, commercial, and industrial consumers. This problem results in frequent equipment damage, reduced efficiency, increased operating costs, and unreliable power supply. Despite several reforms in the Nigerian power sector, issues relating to power quality still persist.

Poor power quality occurs when the supplied electrical power deviates from standard voltage, frequency, or waveform characteristics. Common power quality problems include voltage sags, voltage swells, harmonic distortion, flicker, power interruptions, and unbalanced supply. These conditions negatively affect electrical appliances, especially sensitive equipment such as computers, medical devices, and industrial machines. Electric power quality is the degree to which the voltage, frequency, and waveform of a power supply system conform to established specifications.

II. Poor power quality in Nigerian grid

Most of Nigeria's power generation, transmission, and distribution equipment are old and poorly maintained. Transformers, transmission lines, and switchgears that have exceeded their lifespan still populate most sections of the Nigerian grid. These contribute significantly to voltage fluctuations, frequent faults, and power interruptions. Therefore, aging and inadequate infrastructure are major contributors to poor power quality in the Nigerian grid. Government and power companies should invest in replacing obsolete transformers, transmission lines, and switchgears with modern equipment capable of handling present-day loads.

Due to population growth and increased electricity demand, many distribution transformers and feeders are often times overloaded. When loads exceed design limits, voltage drops occur, and this leads to unstable supply and poor power quality. Distribution networks should be expanded and properly planned to accommodate growing demand. Load balancing across feeders will help reduce voltage drops and overloading. Hence, there is an urgent need for proper load management and network expansion.

Inadequate preventive maintenance of power system components results in frequent breakdown. Loose connections, corroded conductors, and damaged insulators cause voltage instability and supply interruptions. There should be a good scheme for both proactive and reactive maintenance within the power network and power quality improvement devices can also be installed. Devices such as voltage regulators, static VAR compensators, surge protectors, and harmonic filters should be installed at strategic points in the power system to improve voltage stability and reduce harmonics.

The widespread use of non-linear loads such as inverters, variable speed drives, UPS systems, and electronic devices introduces harmonics into the power system. These harmonics distort voltage and current waveforms, reducing power quality. The harmonic distortion in the system can be given by the following equation:

$$THD = \frac{\sqrt{V_2^2 + V_3^2 + V_4^2 + \cdots}}{V_1}$$

Where THD is the total harmonic distortion, V_n is the RMS value of the nth harmonic voltage, and V_1 is the RMS value of the fundamental component. Also, routine inspection and preventive maintenance of power system equipment will reduce faults and improve reliability. Modern monitoring systems can also be installed to detect power quality issues early.

Frequent load shedding, switching of feeders, and clearing of faults in the network also cause voltage sags and swells. These disturbances negatively affect sensitive electrical equipment. Increasing generation capacity and ensuring better coordination between generation, transmission, and distribution will help stabilize voltage and frequency across the system.

Furthermore, inadequate generation capacity and poor coordination between generation and load demand lead to unstable system frequency and voltage variations across the network. Educating consumers on proper electricity usage and enforcing regulations against illegal connections will reduce system stress and improve overall power quality.

Also, unauthorized connections and power theft place unexpected loads on the system, causing unbalanced supply and excessive voltage drops in distribution networks. The integration of renewable energy sources such as solar power at distribution levels can reduce load on the national grid and improve voltage profile in local areas.

III. Power Quality Issues

Power quality is a simple term, yet it describes a multitude of issues that are found in any electrical power system and is a subjective term. The concept of good and bad power depends on the end user. If a piece of equipment functions satisfactorily, the user feels that the power is good. If the equipment does not function as intended or fails prematurely, there is a feeling that the power is bad. In between these limits, several grades or layers of power quality may exist, depending on the perspective of the power user. The understanding of power quality issues is a good starting point for solving any power quality problem [1-13]. Power quality issues contain events which are significant and sudden, and small deviations termed variations. These abnormal conditions are explained in details as follows:

A. Transients: This is an undesirable momentary deviation of the supply voltage or load currents. Transients are generally classified into two categories, (i) Impulsive (ii) Oscillatory. These terms reflect the wave-shape of a current or voltage transient.

i) Impulsive Transient: An impulsive transient is a sudden, non-power frequency change in the steady-state condition of voltage, current, or both, that is unidirectional in polarity (primarily either positive or negative). These are commonly known as switching surges or voltage spikes. They can be caused by circuit breakers out of adjustment, capacitors switching, lightning, or system faults.

ii) Oscillatory Transient: An oscillatory transient consists of a voltage or current whose instantaneous value changes polarity rapidly and is bidirectional. This is a sudden bi-directional non-power frequency change: a rising. For high frequency ringing over 500 kHz of 1- µs duration and for 5- 500 kHz ringing with tens of µs duration, it is likely the results of either the system response or the load response to an impulsive transient, with a frequency of less than 5 kHz and 0.3 – 50 ms duration. Back-to-back capacitor energization results in oscillatory transient currents in the tens of kilohertz. Oscillatory transients with principal frequencies less than 300 Hz can also be found on the distribution system. These are generally associated with Ferro-resonance and transformer energization. The oscillatory transient can lead to transient overvoltage, causes tripping, component failure, hardware reboot is required, software glistens, poor product quality and may damage the power line insulators.

B. Voltage Sag

This is a short-term, few-cycles duration, drop in voltage in the range of 0.1 to 0.9 p.u, for duration greater than half a mains cycle and less than 1 minute. Voltage sags are usually associated with system faults but can also be caused by switching of heavy loads or starting of large motors. Voltage sag can cause loss of production in automated process since a voltage sag trip a motor/system or cause its controller to malfunction, it may be very costly to end user as machine/system downtime, scrap cost, cleanup cost, product quality and repair costs make these types of problems costly. Impact of long duration variation is greater than those of short duration variation [4].

C. Voltage Swell

This is a short term increase in voltage of a few cycles duration. Voltage swell is an increase in RMS voltage in range of 1.1 to 1.8 p.u for duration greater than half a mains cycle and less than 1 minute. Swells are usually associated with system fault conditions, but they are much less common than voltage sags. A swell can occur due to a single line-to-ground fault on the system resulting in a temporary voltage rise on the unfaulted phases. Swells can also be caused by switching off a large load or switching on a large capacitor bank. Voltage swells can put stress on computers and many home appliances, thereby shortening their lives. Voltage swell may also cause tripping of protective circuit of an adjustable speed drive.

D. Interruption

An interruption occurs when the supply voltage or load current decreases to less than 0.1 p.u for a period of time not exceeding 1 minute. Interruptions can be the result of power system faults, equipment failures, and control malfunctions. The interruptions are measured by their duration since the voltage magnitude is always less than 10% of nominal. The duration of an interruption due to a fault on the utility system is determined by utility protective devices and the particular event that is causing the fault. The duration of an interruption due to equipment malfunctions or loose connections can be irregular. Ninety percent of fault on overhead distribution lines are of temporary nature. Typically, these faults result from lightning, tree limbs or animals causing ground or shorts. Distribution lines are protected by a form of circuit breaker called a reclosure. Reclosures interrupt faults, and automatically restore the circuit, or reclose, and if the fault has cleared, the reclosure stays closed. If the fault still persists, the reclosure trips and again automatically close back in. A temporary interruption lasting a few seconds can cause a loss of production, erasing of computer data etc. The cost of such an interruption during peak hours can be very heavy.

E. DC-offset

The presence of a dc voltage or current in an ac power system is termed dc offset. This phenomenon can occur as the result of a geomagnetic disturbance or due to the effect of half-wave rectification. Direct current in alternating current networks can be detrimental due to an increase in transformer saturation, additional stressing of insulation, and other adverse effects. DC offset causes waveform distortion, and can cause saturation in the power transformer magnetic circuits as well as steady state variations.

IV. CONCLUSION

Poor power quality remains a serious challenge in the Nigerian power system, affecting economic growth and quality of life. The major causes include aging infrastructure, overloading, poor maintenance, and harmonic pollution. Addressing these problems requires a combined effort from government, power utilities, and consumers. Through infrastructure upgrades, effective maintenance, power quality management, and improved generation capacity, Nigeria can achieve a more stable and reliable power supply system.

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