

# POWER QUALITY: A RESEARCH REVIEW PROBLEMS AND SOLUTIONS

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## ABSTRACT

The dominant application of electronics today is to process information. The computer industry is the biggest user of semiconductor devices, and consumer electronics. Due to the successful development of semiconductors, electronic system and controls have gained wide acceptance in power, information and computing technology and due to the continuous use of drive systems (rotating machines, controlling thyristors and associated electronic components) in industry and in power stations, and the need to keep such systems running reliably, electronic equipment are becoming an integral part of today's industrial, institutional, and commercial facilities. Unfortunately, the same type of equipment often generates power supply disturbances, which in turns affect other items of equipment, and are more likely to generate the distorting harmonics. These harmonics can cause power to be used inefficiently and can be a source of premature equipment failure that will halt production in industrial processing, will result in loss of life in hospitals, data processing activities in real time such as banking transaction processing may be lost, etc...

The principal aim of this paper is to investigate the most common power quality problems, the effect of the harmonics on the power quality, the ways of evaluating the amount of harmonic distortion present in a power system which lead to isolate the cause of the problem and finally device a solution for a good power quality.

## 1. INTRODUCTION

Understanding power quality can be confusing at best. There have been numerous articles and books concerning power quality [1, 2]. There are two terms known in power systems about the quality of power: Good power quality and poor power quality. Good power quality can be used to describe a power supply that is always available, always within the voltage and frequency tolerances and has a pure noise-free sinusoidal waveshape to all equipment, because most equipment was designed on that basis [3]. Unfortunately, most of the equipment that is manufactured also distorts the voltage [4] on the distribution system, leading to what is known as poor power quality. And thus affecting other equipment that was designed with the expectation of consistent undistorted voltage, and are thus sensitive [5, 6] to power disturbances resulting in reduced performance and will cause equipment mis-operation or premature failure. The cost of power quality problems can be very high and include the cost of downtimes, loss of customer confidence and, in some cases, equipment damage.

Indeed, power quality is an important point in the relationship between suppliers and consumers [7] but might become a contractual obligation that stress on improving voltage quality, availability, performance [8] and efficiency and these improvements will have:

Benefits for industrial customers (customized and flexible availability) and for suppliers- utilities.

## 2. CAUSES OF POWER QUALITY PROBLEMS

In today's fast-paced environments, a huge amount of money is spent on state of the art computer-controlled-equipment and systems. These systems are often installed in "unfriendly" electrical environments, which cause owners, industrial companies and investors a great deal of frustration and disappointment and in many cases, result in a great loss of time and money, and that lead us to ask a valuable question "What is the problem?" The answer to this question could have one or more of the following points:

- \_ Computer malfunctions
- \_ Interrupted manufacturing sequences
- \_ Catastrophic failures
- \_ Erratic equipment behavior
- \_ High electrical maintenance cost.

But whatever the answer is, Chapman [9] has classified them as a power quality problems and the latter is subdivided into two categories:

- Supply system quality problems
- Installation and load related problems

### 2.1 Supply system quality problems

Supply interruption  
Transient interruption  
Transients  
Under voltage/ over voltage  
Voltage dip/ voltage surge  
Voltage imbalance

Flicker  
Harmonic distortion

According to Douglas et al [10] the above problems can be classified into one of three disturbance categories based upon duration:

- Transient disturbances include unipolar transients, oscillatory transients (such as capacitor switching), localized faults and other events typically lasting less than ten milliseconds. Transients can originate internally within the building or externally on utility power lines. They represent about 12 to 15% of all power line problems. These disturbances can cause:
  - \_ Damage to electronic lighting systems
  - \_ Shutdown to sensitive equipment
  - \_ Immediate or latent damage to digital microprocessor controlled equipment.
- Momentary disturbances are voltage increases or decreases (sags, swells, and interruptions) lasting more than 10 milliseconds but less than three seconds. The majority of voltage sags result on utility lines from faults on the distribution or transmission lines and they represent about 60% of all power problems. Voltage swells are the least frequent of the power line problems representing about 2 to 3% of all power problems occurring to industry studies [10]. These momentary disturbances can cause:
  - \_ Sudden decrease in line loads
  - \_ Loosing wiring
  - \_ Re-energizing of power after a utility power interruption, when power comes back in.
- Steady-state disturbances are voltage increases or decreases (undervoltages, overvoltages, and interruptions). Interruptions and power outages can originate from electrical short circuits in building wiring or on utility power lines. These interruptions will cause electrical, computer and electronic equipments shut down and losses in operations and revenues.

## 2.2 Installation and load related problems

The major problems in this category can be classified [11] in one of the three following groups:

- Harmonic currents
- Earth (Ground) leakage currents
- Voltage dips and transients

### 2.2.1 Harmonic currents

These currents will cause wiring, motors and transformers to overheat. The result may be a breakdown of insulation and a significant reduction of equipment lifespan. Some of the adverse effects of concentrated nonlinear loads upon a facility are:

- Nuisance tripping of circuit breakers
- Overvoltage problems
- Metering problems
- Overheating of transformers and induction motors
- Computer malfunctions
- Metering problems
- High levels of neutral-to-ground voltage
- Power factor rate penalties

All non-linear loads generate harmonics. This includes all loads, which use switching to control or convert power, for example:

- switched mode power supplies- computers, office equipment, domestic equipment
- variable speed motor drives
- thyristor controlled heating elements
- dimmer switches
- solid state fluorescent lamp ballasts
- over loading magnetic devices such as motors, lamp ballast and transformers as a result of saturation of the magnetic core material.

### 2.2.2 Earth leakage currents

The principal design consideration for an earthing system is that it must protect people and animals from receiving potentially fatal electric shocks in the event of a fault condition. Now, earth conductors are carrying large leakage current permanently as well as serving as a sink for high frequency noise currents. If for any reason the connection to earth is poor, then the impedance of the primary earth route will be high and earth leakage currents will seek alternative routes to earth. This may result in current flowing in unexpected places with consequent risk should the system be disconnected.

### 2.2.3 Voltage Dips, flat topping and transients

Heavy loads such as air conditioning systems, large motors during the starting process, principally cause Dips. However, flat topping is caused by electronic equipment such as the start-up of printers. The combination of surges and dips in the voltage lead to what is known as voltage Flicker and this latter is caused by the operation of large cyclic loads and can reduce the life of motors drives and electrical contacts.

## 3. OBJECTIVE OF A POWER QUALITY SURVEY

The power quality survey is the first, and perhaps most important, step in identifying and solving power problems cited previously. In other words it is thus designed to locate, identify and eliminate the electrical disturbances which disrupt data collection networks, PLCs, variable speed motor drives,

thyristor controlled heating elements and other sensitive electronic equipment that contain some form of microchip or "logic circuits".

There are two types of power quality surveys:

\_ The first type is a preventative survey, uses a number of tests and inspections to locate potential problems before they cause a production outage.

\_ The second type is, a troubleshooting survey, it is used to locate and eliminate problems as quickly as possible after a production outage.

Whether the investigation involves a simple piece of equipment or the facility's entire electrical system, the survey process typically requires the following steps [10]:

- Planning and preparing the survey
- Inspecting the site
- Monitoring the power
- Analyzing the monitoring and inspection data
- Applying corrective solutions.

From the above steps, the survey should provide the background information and basic methodology and tools required to benchmark the power quality performance and improve the reliability with respect to interruptions. Thus, the process basically involves finding out the

What, Where, When, How and Why of the power-related problems at hand.

\_ Monitor requirements [12, 13]: what are the requirements or what are the specific equipment resources needed, to get the job done.

\_ Where to monitor: depends on where the problems are observed or suspected.

\_ When to monitor: The time when the problem occurs can also provide important clues about the nature of the power problem. If the problem occurs at a certain time of day, the equipment switched on at that time should be suspect. The monitoring period should last at least as long as one "business cycle," which is how long it takes for the process in the facility to repeat itself.

\_ How long to monitor

\_ Data collection and analysis systems

\_ Indices for describing performance

\_ Results of other benchmarking efforts from around the world

\_ Other benefits of the benchmarking effort.

As part of the planning and preparation process it is necessary to obtain a site history for the facility of equipment being investigated. Asking questions of equipment operators or others familiar with operations is an important part of a site history.

### **3.1 Inspecting the site**

The site examination begins by visually inspecting outside the facility and around the immediate

vicinity in order to gain a better perspective of the utility service area.

Inspecting the facility helps to identify equipment that might cause interference. It will also surface electrical distribution system problems such as broken or corroded conduits, hot or noisy transformers, poorly fitted electrical panel covers and more.

Any inspection should include a physical review of the wiring from the critical load to the electrical service entrance and any loads, which might cause power problems, will be identified

### **3.2 Monitoring the power**

To solve a power problem for a single unit of equipment, the monitor should be placed as close to the load as possible. Looking for a power quality problem, need that voltage signal is monitored and finally to find the cause, accurate measurement of power quality issues requires that the monitor accurately [12] measure the voltage and current waveforms.

### **3.3 Analyzing the monitoring and inspection data**

To identify equipment problems, it is key to analyze data in a systematic manner.

First, look for power events that occurred during intervals of equipment malfunction.

Second, identify power events that exceed performance parameters for the affected equipment. Third, review power monitor data to identify unusual or severe events.

Finally, correlate problems found during the physical inspection with equipment symptoms.

## **4. SOLUTIONS**

### **4.1 Solutions to supply system quality problems**

The potential solutions for such problems are dependent on the type of disturbance. However, for the voltage disturbances, such as momentary outage, sags and swells and transient voltages, the most convenient solutions to improve the performance of a sensitive equipment is to install a protective device between the power source and sensitive equipment. There is a wide variety of protective devices [14, 15], each device has a different problem solving function and can be used in a variety of applications. Voltage regulators are installed between the power source and sensitive equipment to control the incoming voltage [16] in order to sustain a constant output voltage, it protects the equipment against overvoltages and undervoltages. However, Transient Voltage Surge Suppressors (TVSS) cuts noise and voltage

transients only, and it does not regulate voltage to limit surges and sags.

## 4.2 Solution of harmonic problems

With current technology, virtually all of today's high performance electronic equipment uses a static power rectifier, which convert alternating current to direct current, and the reverse. It pulls a nonlinear current and the latter induces voltage distortion and when distorted voltage is delivered to equipment designed to expect a sinusoidal voltage, the result is overheating or malfunctions.

Harmonic currents are a fact of life and cannot be eliminated unless nonlinear loads are avoided, all industry is increasingly exposed. Although future developments may provide improved electronic systems producing lower levels of harmonics, the problem must be addressed in current and future installations. Since harmonic currents cannot be prevented, installations must be designed to cope with them. Utility companies impose limits on the harmonic voltage distortion, which a customer's site can impose on the system. Where the utility limits are exceeded, special additional steps must be taken to filter the harmonic content. Active harmonic filters [17] are now becoming available which inject an exactly complimentary harmonic current into the supply to cancel that produced by the nonlinear loads. Harmonic filters will provide a solution, although all ramifications of their use may not be anticipated in advance. Filters types include line-reactors, passive harmonic filters, active harmonic filters [18], electronic feedback filters and special transformers that use out-of phase windings to accomplish harmonic reduction [19].

While these units are effective at reducing the harmonic current as seen by the utility, they do not reduce the harmonic current flowing in the cables of the installation. According to Martin [11] practicing the following measures minimizes the effect of harmonics:

Take account of harmonic generating loads when planning the installation.

- Reduce the number of socket outlets on each circuit and increase the number of circuits.
- Carefully distribute these circuits among the phases to reduce out of balance currents.
- Increase the cross sectional area (CSA) of feeders. "Two sizes up" is a good rule of thumb with a sound technical justification- and it saves energy too!
- Increase the CSA of neutral feeders and distribution panels- twice the phase CSA is recommended. The old practice of using half-sized neutrals is definitely no longer satisfactory!
- Uses 5 core copper cable- one core for each phase and two for the neutral. Keep circuits, which supply harmonic generators- such as

office equipment and variable speed drives- separate from those supplying harmonic hating loads- such as induction motors.

- Maintain records of cable layout and usage. Maintain and upgrade the system carefully.
- Consult the relevant records before making changes.
- Routinely monitor neutral and phase currents. Check for excessive heating in transformers, motors and distribution boards.

## 4.3 Solution of earth leakage problems

The primary purpose of grounding electrical systems is to protect personnel and property if a fault (short circuit) were to occur. The second purpose of a grounding system is to provide a controlled, low impedance path for lightning-induced currents to flow to the earth harmlessly.

Problems can be avoided if it is recognized that the grounding system in electrical installations is no longer designed solely for fault conditions. Wherever modern electronic equipment is used, the earth acts as a key-working component of the electrical installation. As such, it must be given equal consideration in terms of:

- \_ Impedances
- \_ Connections
- \_ Documentation
- \_ Working practices

## 5. CONCLUSION

Semiconductors are the heart of computer industry, unfortunately these electronic components are nonlinear and thus may affect the safe or reliable operation of computers and computer-based equipment. Often more important than the physical effect on the equipment is the loss of productivity resulting from computer equipment failure, miscalculations and downtime. Most of surveys done by different researchers show a high incidence of problems caused by harmonics while problems caused by earth leakage were less common. Although filtering is a solution of reducing the effect on such harmonics on the quality of power, it solves harmonic voltage problems at the frequency to which they are tuned only. And thus changes in the equipment on site will change the harmonic profile, so rendering the filters ineffective.

Thus due to the technology and software now available, monitoring is highly-effective means to detect, solve, and even prevent problems on both utility and customer, it can detect problem conditions throughout the system before they cause equipment malfunctions, and even equipment damage or failure. However, before monitoring a design step is needed and should take into account the electrical environment and define how the

electrical installation must meet the needs of the business.

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