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POWER QUALITY: PROBLEMS, PROTECTION AND SOLUTIONS

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Abstract:

Power Quality (PQ) is the set of limits of electrical properties that allows electrical systems to function in their intended manner without significant loss of performance or life. The term is used to describe electric power that drives an electrical load and the load's ability to function properly with that electric power. Without the proper power, an electrical device (or load) may malfunction, fail prematurely or not operate at all.

Earlier, the main concern of consumers of electricity was the reliability of supply, which is nothing but the continuity of electric supply. However, these days it is not only reliability, the consumer wants; quality of power too is very important to them.

In this paper various PQ Problems, their probable causes and need of protection are presented, then finally some solutions are discussed in short to mitigate PQ Problems.

Keywords: Power Quality, Reliability, Continuity of electric supply, PQ Problems, Causes of PQ Problems, Protection, solutions to PQ Problems.

Introduction:

The electric power industry comprises electric generation (AC power), transmission and ultimately distribution to an electric meter located at the premises of the end user of the electric power. The electricity then moves through the wiring system of the end user until it reaches the load Fig.1. The complexity of the system to move electric energy from the point of production to the point of consumption combined with variations in weather, generation, demand and other factors provide many opportunities for the quality of supply to be compromised.

If electrical equipment operates correctly and reliably without being damaged or stressed, we would say that the electrical power is of good quality. On the other hand, if the electrical equipment malfunctions, is unreliable, or is damaged during normal usage, we would suspect that the power quality is poor. In several processes such as Semiconductor manufacturing or Food processing plants, a voltage dip of very short duration can cost them a substantial amount of money [1].

Thus in this changed scenario in which the whole system increasingly demand quality power, the term POWER QUALITY (PQ) attains increased significance [2].

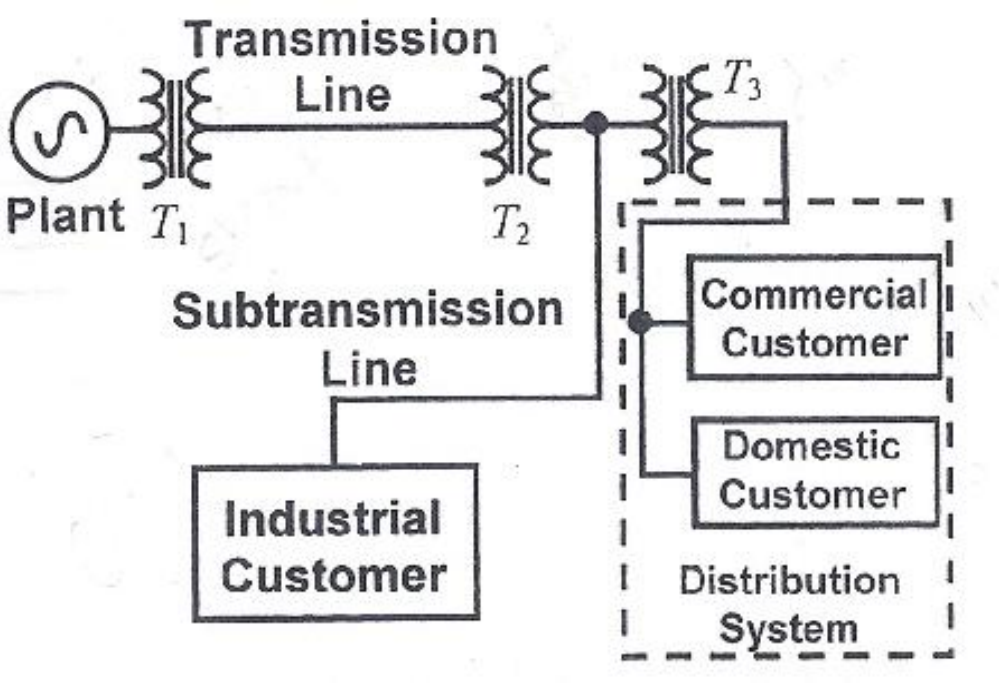


Figure.1: A typical power system

What is power quality?

While "power quality" is a convenient term for many, it is the quality of the voltage - rather than power or electric current - that is actually described by the term. Power quality is the concept of powering and grounding sensitive equipment in a manner that is suitable to the operation of that equipment. We can say "Power quality is simply the interaction of electrical power with electrical equipment."

The ideal ac line supply, by the utility system should be a pure sine wave of fundamental frequency (50/60Hz). In addition, peak of the voltage should be of rated value. Unfortunately the ac line supply that we actually receive not only contains power frequency components but also so-called harmonic components with frequencies equal to a multiple of the power frequency[3]. As a general statement, any deviation from normal voltage can be classified as a power quality issue . Power quality issues can be very high-speed events such as voltage

impulses / transients, high frequency noise, waveshape faults, voltage swells and sags and total power loss. Each type of electrical equipment will be affected differently by power quality issues. By analyzing the electrical power and evaluating the equipment or load, we can determine if a power quality problem exists. [4]

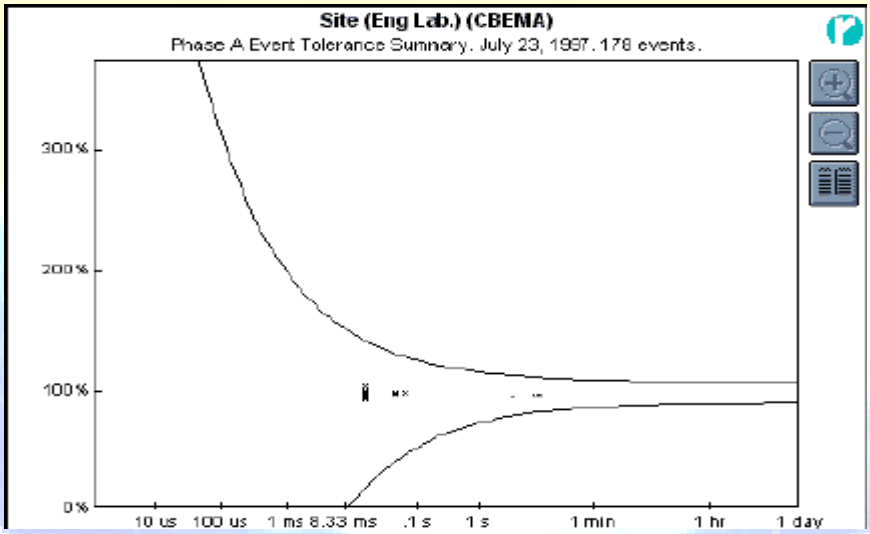
We can verify the power quality by installing a special type of high-speed recording test equipment to monitor the electrical power. This type of test equipment will provide information used in evaluating if the electrical power is of sufficient quality to reliably operate the equipment. The process is similar to a doctor using a heart monitor to record the electrical signals for heart. Monitoring will provide us with valuable data, however the data needs to be interpreted and applied to the type of equipment being powered **e.g.** a standard 100-watt light bulb requires 120 volts to produce the designed light output (measured in lumens). If the voltage drops to 108 volts (-10%), the light bulb still works but puts out less lumens and is dimmer. If the voltage is removed as during a power outage, the light goes out. Either a low voltage or complete power outage does not damage the light bulb. If however the voltage rises to 130 volts (+10%), the light bulb will produce more lumens than it was intended to, causing overheating and stress to the filament wire. The bulb will fail much sooner than its expected design life; therefore, we could conclude that as far as a standard light bulb is concerned, a power quality issue that shortens bulb life is high voltage. We could also conclude that low voltage or a power outage would cause the lumen output to vary, which affects the intended use of the bulb.

The above example can be applied to any electrical or electronic systems. It is the task of the power quality consultant to determine if the power, grounding, and infrastructure of a facility are inadequate to operate the technological equipment. Once this assessment is made steps can be taken to remediate the problems. To use the physician example, the diagnosis has to be made before the medicine is prescribed. Many clients are buying power quality medicine without a proper diagnosis. This is both costly and many times ineffective.

Power Quality Events:

Power quality problems have many names and descriptions. The majority of events currently of interest are associated with either a reduction or an increase in the voltage

magnitude [5]. Surges, spikes, transients, blackouts, noise, are some common descriptions given. Power quality issues can be divided into short duration, long duration, and continuous categories. The computer industry has developed a qualification standard to categorize power quality events. The most common standard is the CBEMA curve (Computer Business Equipment Manufacturing Association). Other standards include ANSI and ITIC. Fig. 2 is an example of the CBEMA curve for site. The various power quality events are plotted on the curve based on time and magnitude. Any event outside the curve would be a suspect power problem.



Site (Eng Lab.) (CBEMA)
Phase A Event Tolerance Summary. July 23, 1997. 178 events.

	Type I	Type II	Type III
Start Duration	1 us	8.333 ms	2 sec
End Duration	8.333 ms	2 sec	1 day
Total Events	0	175	3
Total Faults	0	0	0

	Event No.	Amplitude	Duration
Longest Type I Event	N/A		
Largest Type I Event	N/A		
Longest Type II Event	6400	2.353kV	66.667 ms
Largest Type II Event	12160	2.187kV	16.667 ms
Longest Type II Event	0	2.307kV	8.683 sec
Largest Type III Event	200	2.275kV	3.25 sec

Fig 2: An example of the CBEMA curve

By qualifying the events, we can determine what type of power protection equipment is required to protect the technology.

Power Quality Problems:

There are numerous types of power quality issues and power problems each of which might have varying and diverse causes. To further compound the matter, it is all too common that different power quality problems can occur simultaneously, interchangeably or randomly. The following is a brief summary of typical power problems: [9, 10]

1) Blackout
2) Brownout
3) Voltage Dip (Sag)
4) Voltage Swell
5) Electrical Noise
6) Frequency
7) Harmonics
8) Interruption (Blackout)
9) Noise
10) Notching
11) Overvoltage
12) Short Circuit
13) Transient Surge

Common power quality disturbances include surges, spikes and sags in power source voltage and harmonics (or "noise") on the power line. Each of these occurrences is discussed briefly below:

Surge – A rapid short-term increase in voltage. Surges often are caused when high power demand devices such as air conditioners turn off and the extra voltage is dissipated through the power line. Since sensitive electronic devices require a constant voltage, surges stress delicate components and cause premature failure.

Spike – An extremely high and nearly instantaneous increase in voltage with a very short duration measured in microseconds. Spikes are often caused by lightning or by events such as power coming back on after an outage. A spike can damage or destroy sensitive electronic equipment. Turn the equipment off during a power outage. Wait a few minutes after power is restored before turning it on, and then turn on one device at a time.

Sag – A rapid short-term decrease in voltage. Sag typically is caused by simultaneous high power demand of many electrical devices such as motors, compressors and so on. The effect of sag is to "starve" electronic equipment of power causing unexpected crashes and lost or corrupted data. Sags also reduce the efficiency and life span of equipment such as electric motors.

Noise – A disturbance in the smooth flow of electricity. Often technically referred to as electro-magnetic interference (EMI) or radio frequency interference (RFI). "Harmonics" are a special category of power line noise that causes distortions in electrical voltage. Noise can be caused by motors and electronic devices in the immediate vicinity or far away. Noise can affect performance of some equipment and introduce glitches and errors into software programs and data files.

Outage – Total loss of power for some period of time. Outages are caused by excessive demands on the power system, lightning strikes and accidental damage to power lines. In addition to shutting down all types of electrical equipment, outages cause unexpected data loss.

Causes:

The causes of power quality deteriorating problems are generally complex and difficult to detect. Modern power electronic equipments are not only sensitive to voltage disturbances; they also cause disturbances to other customers . Each individual device does not generate much harmonic current but all of them together cause a serious distortion of the supply voltage [6,7, 8].

We have found that the majority of power quality problems are related to issues within a facility as opposed to the utility. It is found that 90% of power quality problems are caused within the site. Typical problems include grounding and bonding problems, code violations and internally generated power disturbances.

Other internal issues include powering different equipment from the same power source. Let's take an example of a laser printer and a personal computer. Most of us would not think twice about plugging the laser printer into the same power strip that runs the PC. We are more concerned about the software and communication compatibility than the power capability; however, some laser printers can generate neutral-ground voltage swells and line-neutral voltage sags every minute or so. The long term effect to the PC may be power supply failure. We have to be careful in how technology is installed and wired.

Why Power Quality Protection?

While power disturbances occur on all electrical systems, the sensitivity of today's electronics makes more susceptible to them. For some sensitive devices, a momentary disturbance can cause scrambled data, interrupted communications, a frozen mouse, system crashes and equipment failure. [11] A power voltage spike can damage valuable components. Power quality issues can cause business problems such as:

- Lost productivity and idle people and equipment.
- Lost orders, good will, customers and profits.
- Lost transactions and orders not being processed.
- Revenue and accounting problems such as invoices not prepared, payments held up, and early payment discounts missed..

- Customer and/or management dissatisfaction.
- Overtime required to make up for lost work time.

The most common cause of an outage is equipment or component failure, e.g. loss of a generator, transformer or feeder due to faults. Some times utilities have scheduled outages to maintain the power equipment, which involves changing of transformer oil, replacement of a section of feeder conductors or changing of old and faulty switchgear or other equipment. During scheduled outages, a power distribution company may be able to cater to the large majority of the customers by channeling power through alternate feeders or supply transformers wherever available, but this may not be always possible.

It is the unscheduled outages that cause major problems to both utilities and customers alike. These cause higher financial loss to the customers. The impact of even short outages in semiconductor plants can be very severe, so such outages must be minimized. Amongst the unscheduled outages, natural disasters and accidents like earth quakes, floods, blizzards tornadoes fires, arsons, terrorist activities etc cause some. Even if some of these causes can be predicted, it is rather difficult to entirely prevent their impact on the power system.

According to Electric Light and Power magazine, 30 to 40 percent of all business downtime is related to power quality problems [12]. Businesses have a lot invested in office and production equipment, and power quality protection is an inexpensive insurance policy against incidents, at the incoming utility meter and at each piece of sensitive electronic equipment throughout facility.

The Solution:

There are two primary ways of protecting your business against power quality problems: 1) surge suppressors and 2) uninterruptible power supplies (UPS).

.**Surge suppressors –** Surge suppressors are designed to reduce or eliminate potentially damaging short-duration power spikes or surges and electrical "noise." Different types of surge suppressors include:

- **Service entrance surge suppressors.** These devices protect against disturbances in the incoming power supply at the utility meter. They can be inserted at the utility meter socket or hard-wired depending on the application.

- **Plug-in surge suppressors.** These portable wall plug surge suppressors are used at each individual piece of equipment and provide additional protection against disturbances that arise inside the facility.

- **Telephone/cable/modem line suppressors.** These protect against "back door" disturbances introduced through telephone, cable and modem lines. Often they are included as an integral part of a surge suppressor power strip.

Uninterruptible power supplies – UPS equipment contains a battery power supply to provide back-up power to equipment in case of a sudden power failure. They provide continuous power to equipment and protect against even momentary outages or power failures. Systems can be designed to provide enough power for computers and other equipment to be properly shut down without damage or loss of data. Power conditioning UPS can protect against other disturbances such as spikes and noise.

A power quality analyzer that complies with international power quality standards is built based upon COTS (Commercial-Off-The-Shelf) tools such as NI Compact RIO, a rugged and scalable hardware platform and NI Lab VIEW graphical development environment.

A typical power quality analyzer analyses 3 voltages of power network to calculate voltage quality defined in international standards. Voltage quality is described by frequency, voltage level variation, flicker, three-phase system unbalance, harmonic spectra, total harmonic distortion and signaling voltages level. In some cases it is necessary to analyze together with the voltages also the current signals. This allows analysis of current parameters and calculation of indirect quantities like active power, reactive power, energies and other quantities.

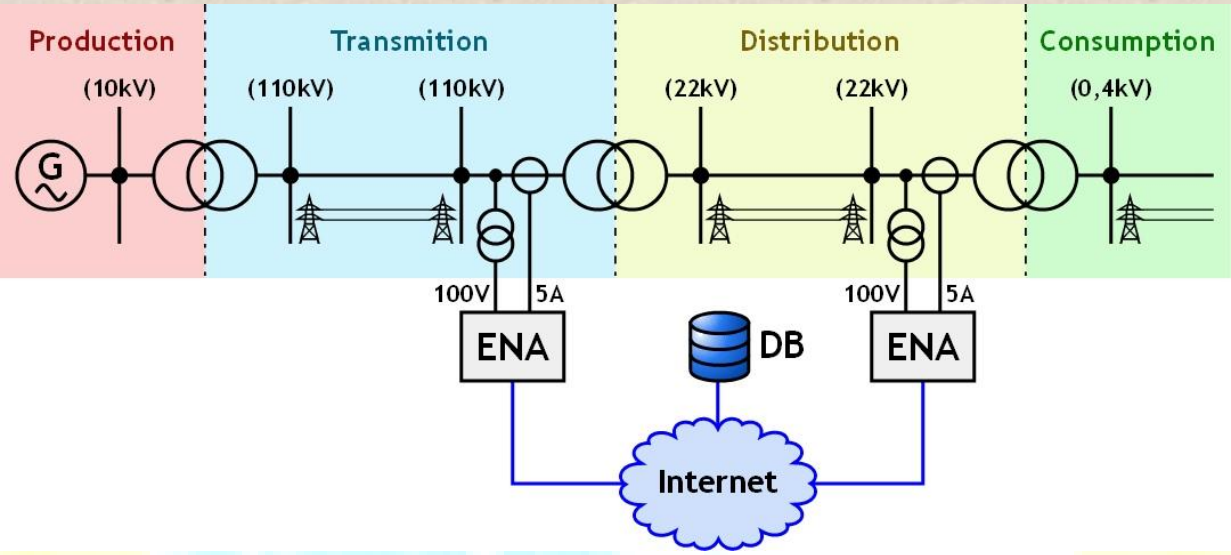


Figure3: Electrical Energy Transmission with Power Quality Monitoring

Our power quality analyzer software and hardware suite is named ENA (ELCOM Network Analyzer) and represents a complex modular system for power quality monitoring according to actual international standards and other national-specific documents.

Coclusion:

Electricity is a product like any other and perhaps is the most essential raw material used by commerce and industry today. It is an unusual commodity because it is required as a continuous flow - it cannot be conveniently stored in quantity - and it cannot be subject to quality assurance checks before it is used. Electricity of poor quality, for example, can cause significant damages in production lines. Therefore, by monitoring power quality, it is possible to identify potential problems before they are big enough to create damages that all too often come with serious financial losses. Prevention, however, is relatively cheap and ranges from simple best-practice-design-considerations to global installations of monitoring and control equipment.

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