Power Quality – The Basics

Everyone who operates sensitive equipment wants a perfect or a flawless source of AC power for their equipment, yet few know or follow the basic steps that will lead to this level of AC power. The goal of this article is to outline the most basic steps required to reach the elusive goal of perfect power quality. This discussion will not address surge protection devices, isolation transformers, power conditioners, automatic voltage regulators, harmonic mitigation devices, UPS systems or generators. This article is on the basics that must be considered before any protection or mitigation device is installed.

The path to quality power is like any project in that the basics must be in place before any further steps are taken. The foundation of a building must be constructed before the balance of the structure should not be constructed. If you proceed without the foundation, the entire project is flawed and doomed to failure. Power Quality is the same. If the basics are not in place, you will not reach your goal and the probability of failure is in the 99.9% range.

Power Quality is often used as a general term to describe the overall condition of the grounding, wiring, and AC power delivered to a facility or equipment. It can be "our power quality is poor", "the power quality is such that this equipment malfunctions", or in rare cases "we are lucky we have very good power quality".

When there are problems, the blame is often wrongly placed on the utility AC power source or some event outside the facility. While the above statements are general, they do not describe anything more than results of the factors contributing to power quality.

A number of issues that directly effect power quality can be put into 5 major headings.

- **Grounding**
- **Facility Wiring**
- **Load Interaction**
- **Equipment Requirements**
- **Equipment Placement**

Grounding is the most basic and a most critical factor. Most facilities are constructed to meet the NEC (National Electrical Code) as well as any local code requirements, and nothing further is thought about the grounding. Depending on the soil conditions, water table level and a number of other factors, the facility may or may not have adequate grounding for the operation of sensitive equipment. Worse yet, 99+% of the time the grounding is not tested to determine the net resistance of the service entrance ground.

Facility Wiring can be installed per code and still be inadequate for sensitive equipment. How can this be? Read the installation instructions of most sensitive equipment and you will learn that low resistance / low impedance grounding is required for proper equipment operation. Compare the minimum requirements of the NEC to the recommendations of the equipment manufacturer. The wiring can meet code and still be very inadequate for operation of sensitive equipment.

As an example consider a computer network consisting of a file server, connected PCs, printers and related equipment. Has a load test been conducted to determine if the outlet you are using for your file server computer is properly wired? How about all the PCs, printers, etc., connected by data lines to the file server? What is the resistance of all the conductors (phase, neutral & ground) of that outlet back through the electrical distribution system? What is the voltage drop under the rated load of the circuit? What other equipment is plugged into the same circuit? What other equipment is on the panel that may adversely effect the file server computer?

Below is a checklist with the minimum information you should know about any electrical outlet before you plug anything into it. This checklist is both an equipment and life safety issue.

- **True RMS line voltage**
- **Percentage of voltage drop under rated load**
- **Voltage between Neutral and Ground**
- **Conductor Resistance Phase (hot), Neutral & Ground**
- **If isolated Ground – Verify by differential resistance test**

Load interaction is often overlooked and but is a very common cause of power quality problems. If you doubt loads interact, connect a hair dryer to the same outlet as your home TV, turn it on, then turn on the TV and try to enjoy a program. You see the effect of the hair dryer to the TV, now imagine the effect of any device that creates dirty power on your sensitive equipment. Remember, for every action there is an equal and opposite reaction. The facility and construction manager for a major fast food chain referred to the power quality issues he faced as a result of poor grounding, bad wiring and the interaction of equipment in their locations. He stated it best. "I cannot see it, smell it, touch it, but it is causing malfunctions and equipment failure and driving us nuts."

If you could see what happens to the power quality on an oscilloscope when a laser printer starts a cycle, you would understand why the computer on the same circuit locks up. The computer is reacting the only why it can when the power quality is not adequate for operation. It locks up. Remember a computer is programmed to stop (freeze in its tracks) when it looses its place. The data could be corrupted further if it were to proceed. To understand how computers react, go into an unfamiliar, dark room and try to maneuver without bumping into something.

Equipment requirements are outlined in the owner's or installation manual of most equipment. The example below will outline an installation common in the workplace today. The HP LaserJet 4 Plus made by Hewlett Packard®. In the Getting Started Guide page A, "Adequate power supply (see your *User's Manual*, Appendix B)." Four (4) PCs with a power draw of 3 amps each plugged into the same circuit (very common) as the HP Laserjet 4 Plus. The number of PCs is often more than 4, but rarely less than 4 in a modular office furniture environment. We are not going to count the other electrical item used in the workplace. Task lights, radios, calculators, pencil sharpeners, personal heaters, etc., and are all commonly on the same circuits as PCs.

OK, we have 4 PCs drawing 12 amps on a 20-amp circuit. Now lets add our printer to this load (tens of thousands of installations are like this). From the HP manual on page B-2 " Highest one second average RMS Current 10.3 amps. Ok, we have a 20-amp circuit that should never be loaded to more than recommended by the NEC, and installed equipment without all the "extras" equaling 22.3 amps. Not only has the NEC recommendations for circuit loading been exceeded, the circuit and circuit breaker capacity has been exceeded. While, such an installation is common, it is very wrong and will be nothing but trouble over the short and long term. Now do you wonder why the PCs may have a problem or the laser printer has a problem?

The example above is but one scenario of how a power quality issue is created by load interaction. Electrical panel loading and branch circuit loading must take into consideration the loads to be powered and the nature of the loads. The interaction of the connected equipment is a very common power quality issue.

Equipment requirements are outlined in the owner's or installation manual, however, are totally ignored until there is a problem. That would compare to someone writing checks until they start to bounce at the bank. Most people would not do that, yet they commonly continue to plug in equipment as if an electrical outlet were an endless source of power.

Equipment's input power requirements and its sensitivity to power that is out of bounds varies with every individual device. Your best source for any equipment's power requirements for any equipment is the owner's manual or installation manual. If you do not find what you need, contact the manufacturer or seek the information on their web site. Ignoring power requirements will certainly cause usage problems and premature equipment failure.

Equipment placement is important because of the possibility interference from outside sources. High voltage conductors will interfere with equipment as a result of the EMI / RFI interference. In manufacturing environments the placement of control microprocessors and PCs is important becauses a nearby device may emit interference and cause the microprocessor or PC equipment problems. Special shielding may be required or at best the device may subject the sensitive equipment to error producing EMI / RFI.

An example of poor planning was the installation of a training room for PC devices on the opposite wall of the primary electrical panels in a large facility. The interference in this case was so strong the monitors of the PCs were distorted. In another case, a production PC was placed next to a switch panel assembly with a very large step down transformer so it could be close to the operator. The plant manager could not understand why the monitor was distorted. He changed the monitor and could not understand why every time he installed a new one it went "bad" and suddenly was OK in another location. Frustrated, the plant manager called the MIS department and they sent a technician to "fix" the problem. The technician and the manager could not figure out the problem so they called in the PC supplier's salesman. The three of them spent 30 minutes looking for the gremlins yet could not find the problem. Later when the line was shut down the operator came to the plant manager's office, he knew what the problem was so he moved the PC a few feet away from the electrical panels and all was fine.

The classic case of what not to do was in a high technology environment. A company that provides testing services to industry and government clients purchased a new piece of test equipment as part of a large contract they had been awarded.

At this location the company laboratory used some equipment that emitted very strong EMI/RFI during one of the test cycles. The new testing equipment that cost just under a million dollars was added to the area to meet the requirements of very valued customers and their new contract.

When the electrician was called in to "wire up" the new equipment he found the only panel that could support the required voltage also provided power to the air compressor and air conditioners. He knew the location well and was more than aware this was the only panel that had enough breaker space so he ran the necessary conduit, mounted the disconnect and carefully followed the installation instructions and code regarding wire size.

When the equipment was powered up for the initial benchmark testing, it did not operate properly even one time over a term of several weeks. The electrician was called back and went over the installation with the test equipment technician. They both confirmed the electrician had installed the breakers, wires, etc., all per the installation manual. After several trips to the site, the electrician told the customer he would charge for any further calls as he only did what he was told to do and the installation was correct. It was not his fault the equipment did not work and it was up to the equipment supplier to figure out what was wrong with their machine.

What was done wrong? No one bothered to read the installation manual past the pages that stated the wire size and disconnect required. They all made assumptions during the installation as to the condition of the ground and electrical service. Not one of those involved considered anything past the new circuit.

The company building was constructed in the mid 1980's and the electrical service entrance ground was assumed to be OK. After testing the service ground (fall-of-potential), it was found to be 187 Ohms. The installation manual stated the ground must be less than 1 Ohm in the reference section. The test by the electrician was only to test the ground wire he installed back to the main panel, not test the building service entrance ground.

The AC panel powering the new *VERY* sensitive test equipment that was just installed also powered a 20-ton AC compressor and a 15-hp electric motor for the air compressor. This panel was very heavily loaded before the test equipment was added and no one looked at the power requirements of the new test equipment. The manual stated the input voltage must be ± 4% or the test data would be flawed.

In addition to the high inrush current devices (AC compressor & 15-hp motor) on the panel, it also supported the 277 volt lighting with electronic ballast. The high frequency noise and harmonics generated far exceeded the input power specifications of the new test equipment. The manual stated that the neutral to ground voltage must not exceed .1 volts. The average neutral to ground voltage in the facility was over 3 volts. At the new equipment it was just under .5 volts.

The location of the test equipment was next to the worst source of EMI/RFI in the building, a very large spectrometer. The spectrometer was not adequately shielded and was not properly grounded. When the spectrometer was installed the installation manual called for an isolated ground, so the installers placed a ground rod at the installation location and did not bond it to the electrical ground.

The solution was to create a proper environment and provide clean, stable power and the new test equipment worked properly. Cost to the company before the problem was solved? They lost a contract with a major customer and still had to pay for the equipment they purchased to meet the contract.

The only up side to this example is that their competitor could not meet the contract for some reason and the company was able to get the contract back after the power quality issues were resolved and the equipment was running properly. The bottom line cost? The president of the company will only give you a glum look when asked and walk off grumbling.