Investigating, Testing and Measurements

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Abstract

99.9% of all power quality problems originate inside the manufacturing or commercial facility. The use of solid state power conversion is detrimental to the power quality, such as IGBTs, Variable Frequency Drives (VFDs) and so on. The article will focus on identifying these phenomenon's and propose a possible correction.

The first part of this article concentrates on measurements and investigation, while the second part concentrates on mitigation.

With this kind of approach, it is necessary to do the mitigation due to the fact that non-linear devices (such as solid state) impact the consumption of electrical current. The article also discusses other possible methods of mitigation.

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Investigating power quality problems requires a strategy for investigation. The most common pitfall with power quality problems is that it is perceived a problem of the supply utility. Speaking from experience of over 10 years in power quality correction, the utility supplies power at the common point of coupling (at the metering point and the connection point to the facility) that is within the parameters of power quality standards.

Power Quality problems can originate from 2 areas:

1. Outside the facility, i.e. from the utility.
2. Inside the facility, i.e. from the usage of the power.

1. The utility

In order to supply the same level of voltage the utilities frequently support the distribution system with capacitors which are switched in and out as the load varies on the distribution grid. This capacitor switching introduces a high frequency ring wave that may excite some portions of the distribution to the point where equipment will malfunction. There are also events that are not in the control of the utility such as wind, lightning storms or physical damage to their distribution equipment.

2. Inside the Facility

Apart from these factors we have to look at the internal electrical distribution and its integrity.

99.9% of the power quality problems are created internally.

Addressing Power Quality within the facility.

It is necessary to organize our strategy and approach before we start investing in expensive monitoring equipment. The best way is to keep a maintenance log of breakdown by equipment, showing time of day, problem, correction and anything else that may be useful information such as weather conditions or loading. If possible record all anomalies and disturbances and be suspicious of every possible influence.

It is necessary to be certain that the grounding system is sound and we do not have ground loops. Also, that all connections are good in order to provide a low impedance path to ground. The next step would be to take an inventory of the type of loads that are on the distribution, and to record recent changes in equipment such as lighting upgrades (i.e. replacing ballasts with electronic ballasts) computer upgrades and conversion to automated equipment within the facility.

From our maintenance log we can look for coincidences of disruptions and record the time, day and other conditions as well as load conditions. The last avenue would be doing further investigation by testing and doing measurements in a power quality analysis. It is recommended to have a power analysis done by retaining an expert in this field. Many of the power quality problems are a call of experience and require much experience to correct the problem. That is why there is a long learning curve to become a good power quality analyst. Power quality analysts need to be consistently involved with power quality and power utilization. Mainly because the equipment is becoming faster, more efficient as well as more sensitive and it is necessary to keep up with the changes.

It is necessary also to be familiar with power quality standards and their applications. Most of the power quality standards are based on a CBEMA curve which was developed by Computer Business Equipment Manufacturers Association and was adopted as a power quality standard in the late 1980s'. This "standard" is irrelevant and not applicable to today's electrical distribution system environment.

There is power monitoring equipment on the market that is based on the above mentioned standard (CBEMA). This equipment monitors the power and confirms compliance to the CBEMA standard curve. In many cases the instrument deems the power quality to be good, however, the user is still experiencing untold problems with power quality.

IEEE 519 standard was first developed in 1992 and was adopted as a power quality standard for harmonics. This standard is applicable to harmonics however its application sometimes leaves a gray area, mainly because the IEEE 519 standard highly relies on the common point of coupling for harmonics compliance. A common point of coupling is where the offending equipment is installed or where the offended equipment is installed. From the utility point of view it is the metering point or connection point to the facility. It is quite common that no unusual events are recorded at the utility common point of coupling however downstream in the facility the problems can be frustrating. This standard also relies on short circuit/load capacity, which is rarely known to the user.

All of the other power quality standards such as IEC, ANSI standards are similar to the ones mentioned above, but none of them address the whole spectrum of power quality. It is therefore necessary to know which standard is applicable in each individual situation and how it should be applied.

There are many different types of monitoring and/or measuring equipment on the market, each with different features and capabilities. It is important to know what it is one is looking for; grounding problems, electro-magnetic interference, flicker effect, resonance, transients or any other type of disturbances. Each one of these power quality aspects affect the operation of the equipment in a different manner.

The most effective way to determine monitoring and measurements required is to understand the operation of non-lineal equipment. That narrows down the spectrum of problems, or phenomenon that we need to examine. The monitoring equipment even though it may have a report writing feature is not capable of determining whether an event is going to be the source of the problem or is relevant. The relevancy of the event is dependant on the impedance of the electrical distribution system or the particular branches of the distribution where the problems are experienced.

When performing power quality analysis you want to see simultaneously transients, harmonics, swells, dips, as well as power elements such as kVAR, KVA, KW, Power Factor, Voltage and Current. Equipment that is capable of measuring all these parameters simultaneously and is able to capture fast moving transients is expensive and requires experience in interpreting the data it provides.

Once the measurements are obtained a detailed diagram of the facilities electrical distribution system has to be drawn up and a short circuit and load flow analysis need to be done in order to determine the short circuit capacities at the offending point of common coupling. With this information simulations of transients or harmonics can be done to study their interaction. Knowing the sensitive equipment and its operation you can isolate the problem areas and suggest appropriate mitigation.

Harmonics are created by converters, rectifiers, inverters which are an integral part of most manufacturing equipment. These harmonics are what we refer to as "characteristic" harmonics because they are the same from cycle to cycle. Characteristic harmonics are predictable and the harmonic orders (3^{rd}, 5^{th} etc.) are predictable. The magnitudes of each may vary according to the load conditions but they are of a fairly steady state. Non-characteristic harmonics are harmonics created by arc furnaces, resistance welders and arc welders. The reason why these harmonics are non-characteristic is because they sweep through the whole harmonics spectrum and vary from cycle to cycle. Therefore they are the most difficult to mitigate.

To take a black and white approach where 5% of harmonic current is too much or too low is inappropriate because it is possible to have equipment producing well in excess of 60% current harmonics and not impact any other equipment on the system. On the other hand, a 3% current harmonics in certain situations can cause a catastrophic failure. Understanding the equipment operation and process is necessary to identifying the problem.

Transients are caused by fast switching solid state devices such as SCR's, thyristors, GTO's and IGBT's. Due to their fast switching characteristics the capacitive components of the circuit do not have enough time to discharge and usually have the peak voltage (DC) of the AC sine wave. Therefore, as these devices switch, transients are reflected back to the electrical distribution system. These transients are of a higher frequency than the fundamental frequency and therefore the 60 cycle source is not necessarily the lowest impedance path. Another piece of equipment may offer a lower impedance path and the transient will deteriorate and damage that piece of equipment.

 # 4 AWG BUILDING WIRE (25 mm^2)

LENGTH	L (> MHz)	@ 1 MHz		@ 10 MHz		@ 100 MHz	
		Rf	:= Z	Rf	:= Z	Rf	:= Z
10 ft.	4μH	0.05ς	26ς	0.15ς	260ς	0.5ς	2.6kς
20 ft.	9μH	0.1ς	57ς	0.3ς	570ς	1.0ς	5.7kς
40 ft.	20μH	0.2ς	125ς	0.6ς	1.25kς	2.0ς	12.5kς
60 ft.	31μH	0.3ς	197ς	0.9ς	1.97kς	3.0ς	19.7kς
100 ft.	55μH	0.5ς	350ς	1.5ς	3.5kς	5.0ς	35.0kς

 # 4/0 AWG BUILDING WIRE (107 mm^2)

LENGTH	L (> MHz)	@ 1 MHz		@ 10 MHz		@ 100 MHz	
		Rf	:= Z	Rf	:= Z	Rf	:= Z
10 ft.	3.6μH	0.022ς	23ς	0.07ς	230ς	0.22ς	2.3kς
20 ft.	8μH	0.044ς	51ς	0.14ς	510ς	0.44ς	5.1kς
40 ft.	18μH	0.088ς	113ς	0.28ς	1.13kς	0.88ς	11.3kς
60 ft.	28μH	0.132ς	176ς	0.42ς	1.76kς	1.32ς	117.6kς
100 ft.	50μH	0.220ς	314ς	0.70ς	3.14kς	2.20ς	31.4kς

<u>Impedances</u>

The grounding system should be the lowest impedance path in the electrical distribution system. However, if we have ground loops, the impedance of the grounding system increases also the impedance of the grounding changes if the frequency increases. Most common grounding problems occur due to the fact that the national electrical code is a standard that requires minimum compliance, which is not always the best for the circumstances. As a result, sometimes the grounding becomes insufficient. Another problem with the grounding is that specification for grounding are often sadly missing in the engineering specifications for the electrical distribution system. To compact the grounding problem there is also different grounding philosophies among engineers (electrical engineer vs. electronics engineer or telecommunication engineers). In addition, the installing electrician of the grounding system is left up to his own devices and interpretation of the grounding system and believe me they can become ingenious when they execute the job. The last pitfall most overlooked is that even places with good maintenance practices, neglect to maintain the grounding of the electrical distribution system.

Another infrequent power problem is electro-magnetic interference which is usually radiated and occasionally directly coupled into the electrical system by accidental over-sight and/or poor planning. It may have a detrimental effect on reliable equipment operation, mainly of data processing equipment.

As you can see from this article, the problems of power quality are varied and therefore require a good understanding of the electrical distribution system and how electrical and electronic equipment interact.