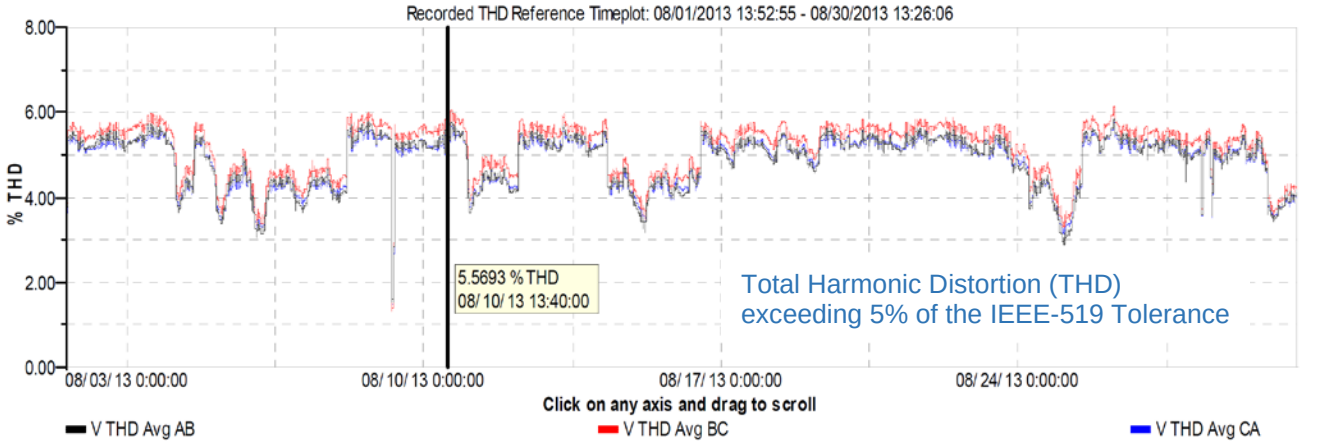
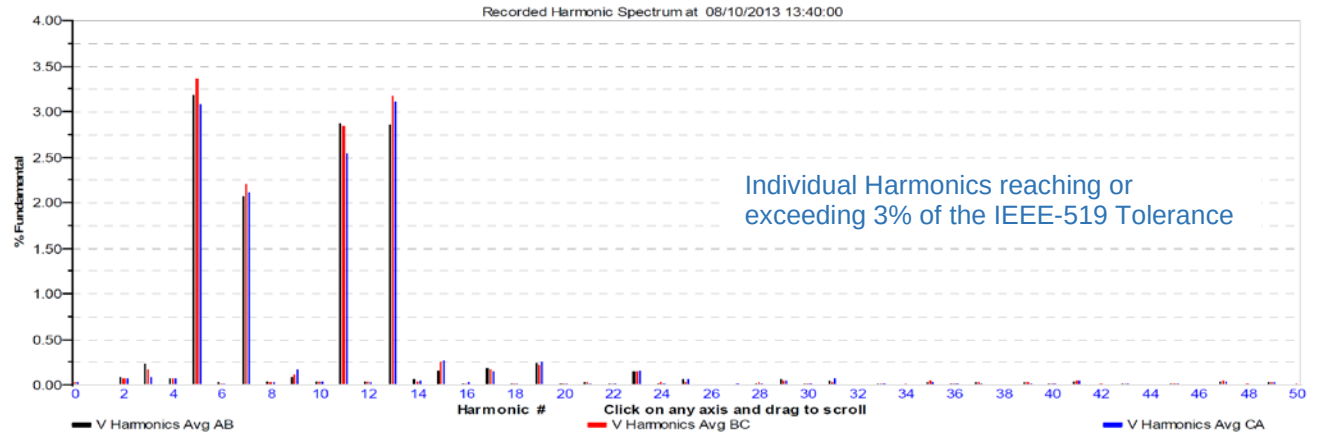
POWER ANOMALIES - Review of Voltage Harmonics

Harmonics are distortion on the voltage or current sine wave. Harmonics occur on multiples of the fundamental frequency. The fundamental frequency in the US is 60 Hz. Multiple frequencies are therefore 120 Hz, 180 Hz, 240 Hz, etc …

IEEE-519 standard defines the acceptable practice (limit) for voltage harmonics. IEEE-519 states that Voltage Waveform Distortion must not exceed 5% Total Harmonic Distortion (THD) and/or 3% of the Individual Harmonics in the electrical distribution system at the Point of Common Coupling (PCC). This is commonly defined as the service entrance to the healthcare facility. In addition to IEEE-519 setting harmonic standards, the electric utility will also require lower harmonic content. ***High harmonic content may impose a penalty by the utility in the form of higher costs.*** The image below displays THD exceeding the 5% limit *(top image)*. The next image below displays individual harmonics exceeding the 3% limit *(bottom image)*. The 5th and the 13th harmonics exceed the 3% limit. The 11th harmonic is reaching the 3% threshold. These images were captured with a Fluke 1750 meter.





Voltage Harmonic issues have become more commonplace in Healthcare Facilities. These high levels of THD are generally due to non-linear loads (loads that draw non-sinusoidal current from a voltage source that is sinusoidal). Non-linear loads are created by Variable Frequency Drives (VFDs) used with large motors, switch-mode power supplies, and UPS System rectifier circuits.

Switch-mode power supplies create high levels of 3rd harmonics. VFDs and UPS Systems with 6 and 12 pulse rectifiers will also cause high levels of harmonic content. Six pulse rectifiers create high levels of the 5th and 7th odd harmonics. Additional harmonic currents will be found on the 11th, 13th, 17th, 19th, 23rd, 25th, and so on … Twelve pulse rectifiers create higher harmonic levels at the 11th and

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13th harmonics with additional harmonic currents at the 23rd, 25th, and so on … A rough Rule of Thumb states that the magnitudes of the harmonic currents will be the fundamental current divided by the harmonic number. UPS Systems and VFD's with Insulated Bipolar Gate Transistor (IGBT) converters (rectifiers) generate far lower reflected current harmonics and therefore lower voltage harmonics on the electrical distribution within the facility. There is a relationship between the current harmonics and the voltage harmonics.

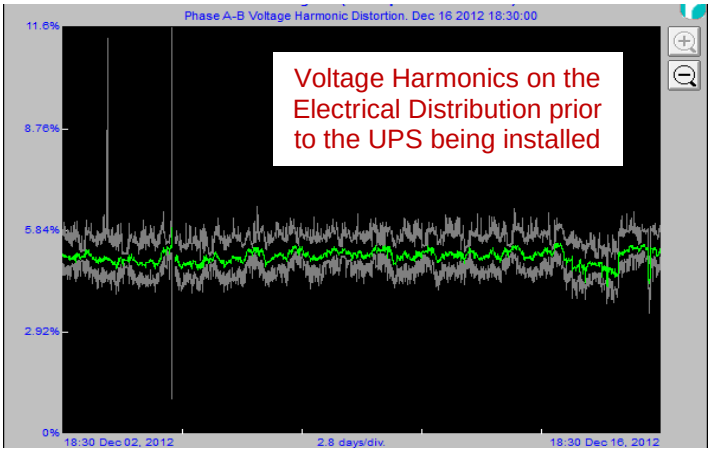
Rectifier Pulse #	6 Pulse	12 Pulse	18 Pulse/IGBT
≈ Current THD Produced	25-30%	12-15%	3-5%

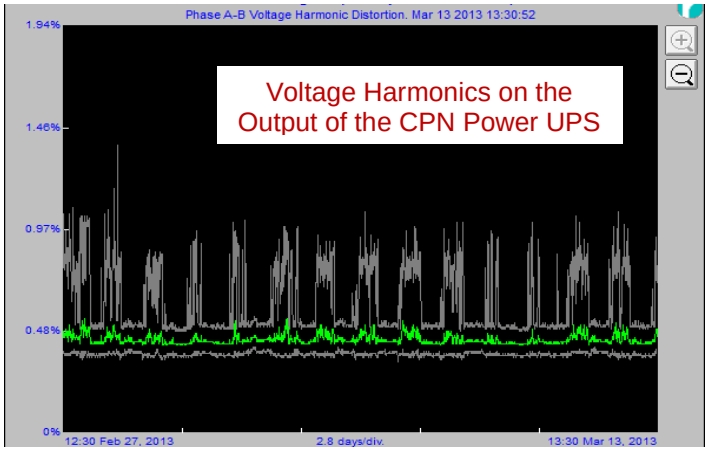
The potential effects of high harmonics are higher component operating temperatures in the medical equipment components and improper zero voltage crossing detection, which can cause misoperation of electronic equipment. ***High voltage harmonics will also cause image quality issues with Diagnostic Imaging equipment.*** As the THD increases, the likelihood of problems also increases. For that reason, Medical Equipment Vendors recommend harmonic content levels that do not exceed IEEE-529 standards. If THD *or* individual harmonic content exceed these standards, then action is required to reduce the voltage harmonics to an acceptable level.

The preferred approach toward resolving harmonic issues is to resolve them at the source of the problem. Applying 18 Pulse VFD's and UPS Systems with IGBT rectifiers will help to keep harmonics at a reasonable level. Applying proper filters with 6 or 12 Pulse rectifier designs will also reduce the THD. In some cases, resolving the issue at the source can be near impossible or just too costly. When this is the case, the most common approach toward reducing the harmonics for medical equipment, such as an MRI, is to install a Double Conversion Power Conditioner (DCPC - a UPS module without batteries or flywheel) or a complete Double Conversion UPS System. NOTE: A line-interactive UPS design or a Double Conversion UPS in Eco-Mode will not resolve high harmonic issues.

The CPN Power DCPC will protect against voltage swells/sags in the range of +10% to -20% (-30% under low load conditions for short duration voltage sags), and lower amplitude high frequency voltage transients. An input TVSS device in conjunction with the UPS is good practice for complete High Frequency Voltage Transient (HFVT) protection. The DCPC additionally protects against low frequency transients, frequency deviations, phase imbalance, voltage waveform distortion, and assures tight ±1% voltage regulation during peak momentary current inrush conditions. The complete UPS System will additionally protect against deep voltage sags, single phasing, and complete outages. NOTE: The battery or flywheel backup time will determine the protection timeframe.

The images below display the input voltage harmonic levels *(left image)* in a healthcare facility prior to the installation of the UPS System. The voltage harmonics were ≈5% prior to the UPS installation. The voltage harmonics on the output of the CPN Power 750 kVA UPS System *(right image)* are ≈0.5% on average with THD reaching 1% during peak current activity. These images were captured with a Fluke (RPM) 1650 meter.





There are many benefits achieved by installing a DCPC or UPS to protect medical equipment. As noted above, one important benefit is to provide reduced voltage harmonics on the UPS output, resulting in better image quality.