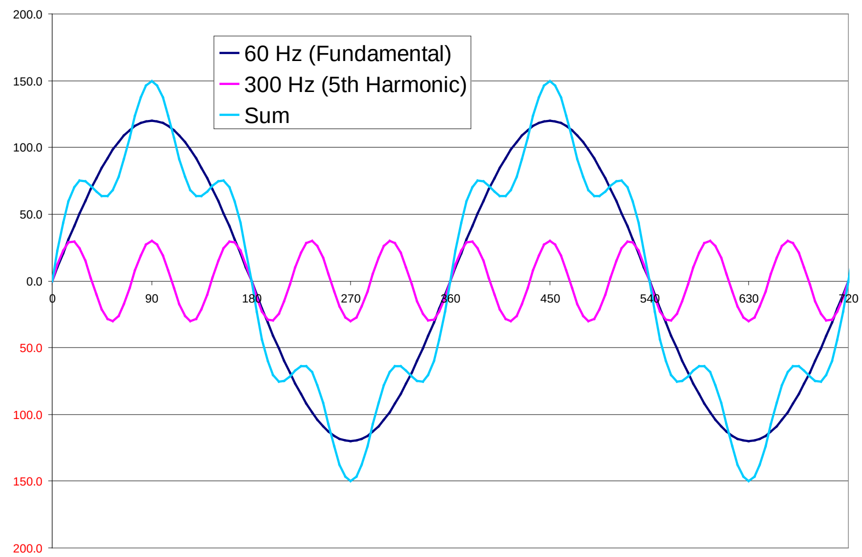
Understanding Harmonic Measurements with the Powermaster

As loads become increasingly non-linear, harmonics are becoming more prevalent at customer locations. Without a large digression into harmonic theory, there are still some basic information that everybody should know, including how the Powermaster displays harmonics, and how to interpret what is seen on the harmonic display on the Powermaster.

What Are Harmonics?

Harmonics are sinusoidal voltages or currents having frequencies that are whole multiples of the frequency at which the supply system is designed to operate. In the US, this is 60Hz, thus a 2nd harmonic would have a frequency of 120Hz, a 3rd harmonic would be 180Hz, etc. Some notations show the fundamental as the 1st harmonic. Each harmonic is added to the fundamental, creating a complex wave shape that contains the fundamental and each harmonic, as shown below.



The light blue wave form is the sum of the fundamental 60Hz (dark blue) and the 500 Hz 5th harmonic (the pink waveform).

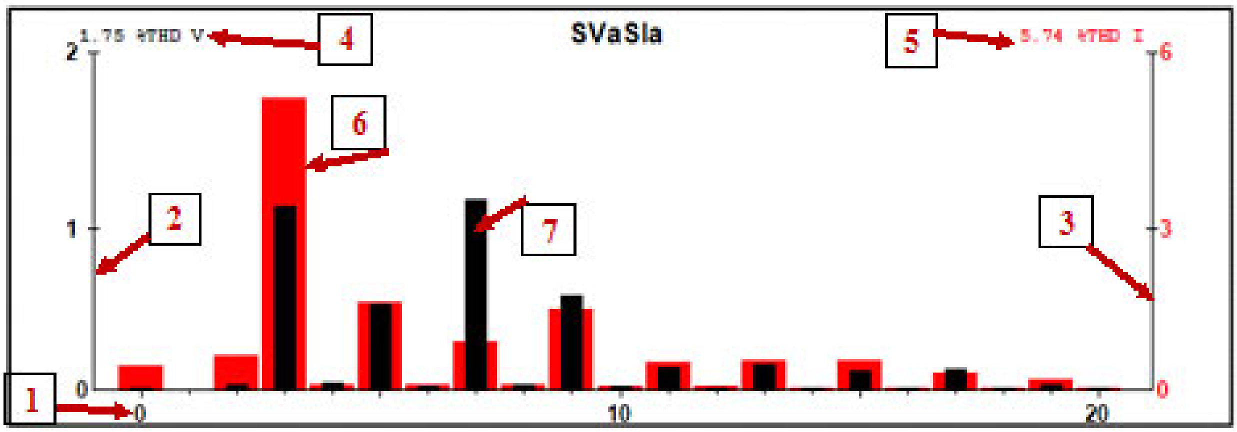
What Causes Harmonics?

Harmonics are created by non-linear loads, which is caused when the loads impedance changes with applied voltage, causing distortion on the current waveform. A few sources of non-linear loads are LED's, CFL's, VFD's and computer power supplies.

Why do harmonics matter?

Harmonics can cause overheating in neutral conductors, equipment malfunction or damage, erratic behavior of sensitive breakers and relays, and even damage to power factor correction capacitors.

How Does the Powermaster Help?
The Powermaster displays harmonics in a typical bar type scenario, as shown below. This feature is accessed via the hotkeys to the right of the display screen. To save a snapshot of the harmonics, once the graph is displayed, press F6 to stop acquisition, then press F1 to save. This will attach a harmonic data sheet to the site ID you currently have selected.



At first glance this may be confusing to look at, but it is a simple way of taking a quick glance at harmonic content.

1. This is the harmonic order, with each marker on the axis indicating a harmonic. *Note* The fundamental is not displayed.
2. Magnitude of the Voltage harmonics. In this case the scale goes up to 2% for the Voltage
3. Magnitude of the Current harmonics. In this case the scale goes up to 6% for the current.
4. Voltage total harmonic distortion, expressed in %THD V.
5. Current total harmonic distortion, expressed in %THD I.
6. Current is the red bar.
7. Voltage is the black bar.

An overview of this graph would tell me the voltage (1.75%THD) and current (5.74%THD) distortion, plus significant harmonics (here, the 3rd, 5th, 7th, and 11th). Pay attention to the scales on either side of the graph, plus the %THD in the top of the graph to determine the magnitude of the harmonics.

Harmonics: Sequences

Harmonic Sequences
To help understand which harmonics can cause problems, harmonics can be divided into what are called sequences. Harmonic sequence refers to the phasor rotation of the harmonic voltages and currents with respect to the fundamental waveform, in a balanced, 3-phase 4-wire system. The three sequences are Positive sequence, Negative sequence and Zero sequence harmonics.

The problems caused by the harmonics will be related to their sequence. The below graph shows a few harmonics and the sequence they fall into.

Name	F	2nd	3rd	4th	5th	6th	7th	8th	9th
Freq	60	120	180	240	300	360	420	480	540
Seq	+	-	0	+	-	0	+	-	0

Positive Sequence Harmonics
Positive sequence start with the fundamental, then occur every third one after that. The 1st, 4th, 7th, 10th, 13th, etc, are called positive sequence harmonics. Positive sequence harmonics rotate forward, or in the same direction as the fundamental. These can cause overheating of conductors and transformers due to the addition of the waveforms. If such harmonics are present in a large amount, conductors and transformers must either be sized appropriately to compensate for the additional magnitude, or some form of harmonic mitigation needs to be employed.

Negative Sequence Harmonics
Negative sequence harmonics begin with the 2nd, and occur every third harmonic thereafter. The 2nd, 5th, 8th, 11th and so on are negative sequence harmonics. As opposed to positive sequence harmonics, negative sequence circulate between the phases, in the opposite direction of the fundamental. This opposite rotation causes weakening magnetic fields in motors (especially induction) and results in a loss of mechanical torque.

Zero Sequence Harmonics
Zero sequence harmonics, also more commonly referred to as "triplens" begin with the third, and every third harmonic thereafter. All zero harmonics are a multiple of 3 (3rd, 6th, 9th, 12th, 15th), hence the name triplen. They have zero rotation sequence and circulate between the phase and neutral conductors. These harmonics add up in the neutral conductor (along with currents from the other three phases) and can cause overheating in the neutral. Depending on the magnitude of the harmonic current, the neutral current can at times be upwards of 3 times the phase current, resulting in overheating of the wire and less efficiency all around.

Harmonic Solutions

A bit of information to be aware of when dealing with harmonics and attempting to find solutions for them. There is no fast and quick solution for harmonics, no one size fits all type of solution. Each installation is different, and even though they may have the same harmonics, the sources and solutions could be different. Before attempting any type of harmonic mitigation, a full analysis should be performed, and a determination should be made on which harmonics need mitigation, would it be better to replace the "offending" equipment, or should nothing be done at all.

Active Filter

Active filters are a unique type of power electronic solution to mitigating harmonics. Depending on the manufacture and the brand of filter, there are a couple of ways they can be installed and utilized. On an overall synopsis, they monitor the voltage and current, and create an inverse wave of equal magnitude to cancel the harmonics on the system. They can be installed in series or in parallel, depending on the type of load, the magnitude of the harmonics, and the desired outcome. What sets the active filter apart from other forms of mitigation is there is an internal processor monitoring the waveform in real-time and actively correcting the wave-shape.

Passive Filter

A more well-known solution is a passive filter. A passive filter is usually a tuned reactive circuit that is designed to eliminate or drastically reduce a specific harmonic component. By tuning a LC circuit to a specific harmonic frequency, the passive filter creates a low impedance path for the harmonic to flow through. Unlike active filters, passive filters will typically target one harmonic, and has no power electronics on board for active measurements.

Neutral Current Filter

Since currents that flow through the neutral conductor can create overheating due to under sized wire, using a neutral current filter makes sense. The filter itself is designed to eliminate or reduce triplen harmonics, or zero sequence harmonics.

Zig Zag Transformer

This method reduces 5^{th} and 7^{th}, and depending on how it is installed, can also trap triplens inside the windings of the transformer. By utilizing phase shifting in a three phase transformer that is designed with a low zero sequence impedance, and installing it in parallel with the load, a zero sequence current path is created, which eliminates the triplens.

Any Harmonic with large enough magnitudes are harmful to electrical infrastructure. Understanding what sequence the dominant harmonics belong too, and the possible results of that sequence, will allow one to properly mitigate the harmonics as needed to reduce harm and damage to a system. The four solutions listed above are just a few means to mitigate harmonics. As mentioned before, there is no one size fits all solution; however understanding how they can be mitigated can help spearhead an investigation into what outcome is most desired.