Harmonics

By Dan Maxcy 6/21/01

What is a Harmonic?

A harmonic is the term used for unwanted and possibly destructive current flow on your facilities conductors (wiring). They are most prevalent on your neutral conductors.

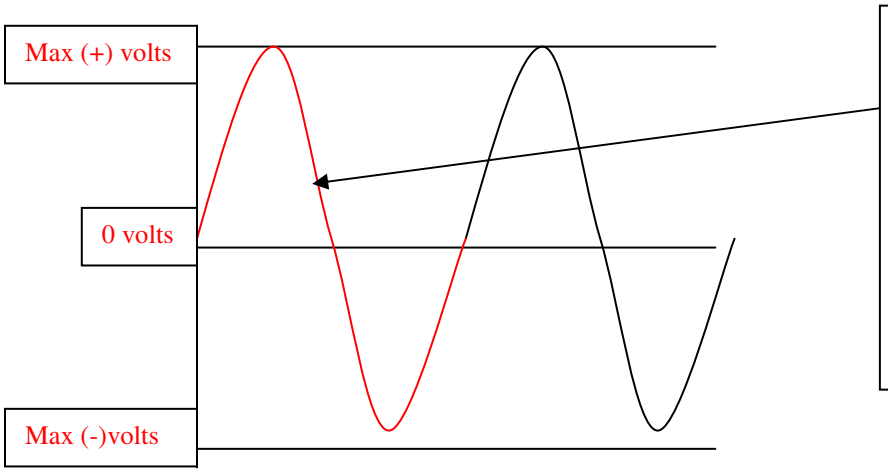
Harmonic problems include:

Overheating and failure of transformers, motors, lighting, switchgear, motor control centers, power correction capacitors, and solid-state equipment. The presence of harmonics can cause electrical, electronic, and computer equipment damage along with data corruption. Control system errors can develop due to electrical noise caused by harmonics. Harmonic currents can cause blown fuses for no APPARENT reason. Harmonic currents can also cause nuisance tripping of circuit breakers.

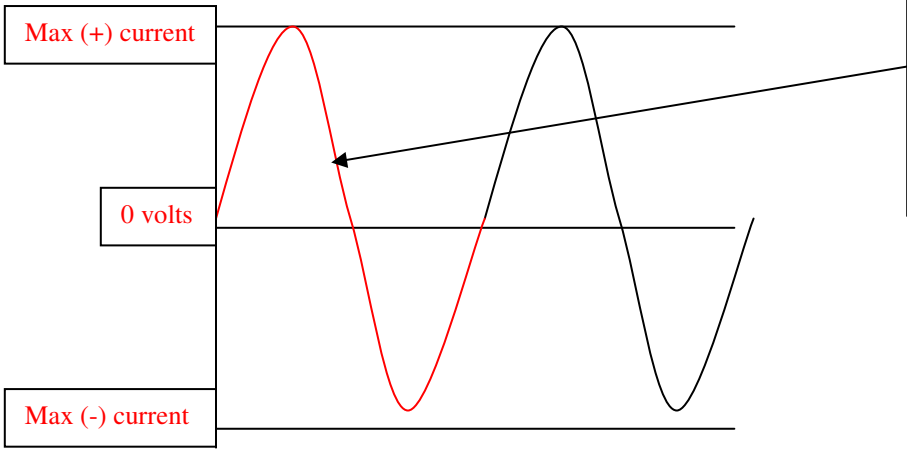
What exactly is a Harmonic?

In a system without harmonics, voltage and current are used in a LINEAR fashion. What is meant by "LINEAR"?

Linear Voltage and Current:



In the United States, the voltage in your power systems goes from 0 volts to a maximum positive voltage back to zero, to a maximum negative voltage 60 times a second. This is called 60 cycles or 60 Hertz. 60 Hertz is also called the frequency since it happens 60 times a second.



Because of the voltage cycling, the current in your system also goes from 0 amps to a maximum positive amperage back to zero to a maximum negative amperage 60 times a second.

This concept of the voltage and current going from zero to a maximum positive back to zero to a maximum negative back to zero in sequence with each other is what is called "LINEAR" system loading or "Linear loads".

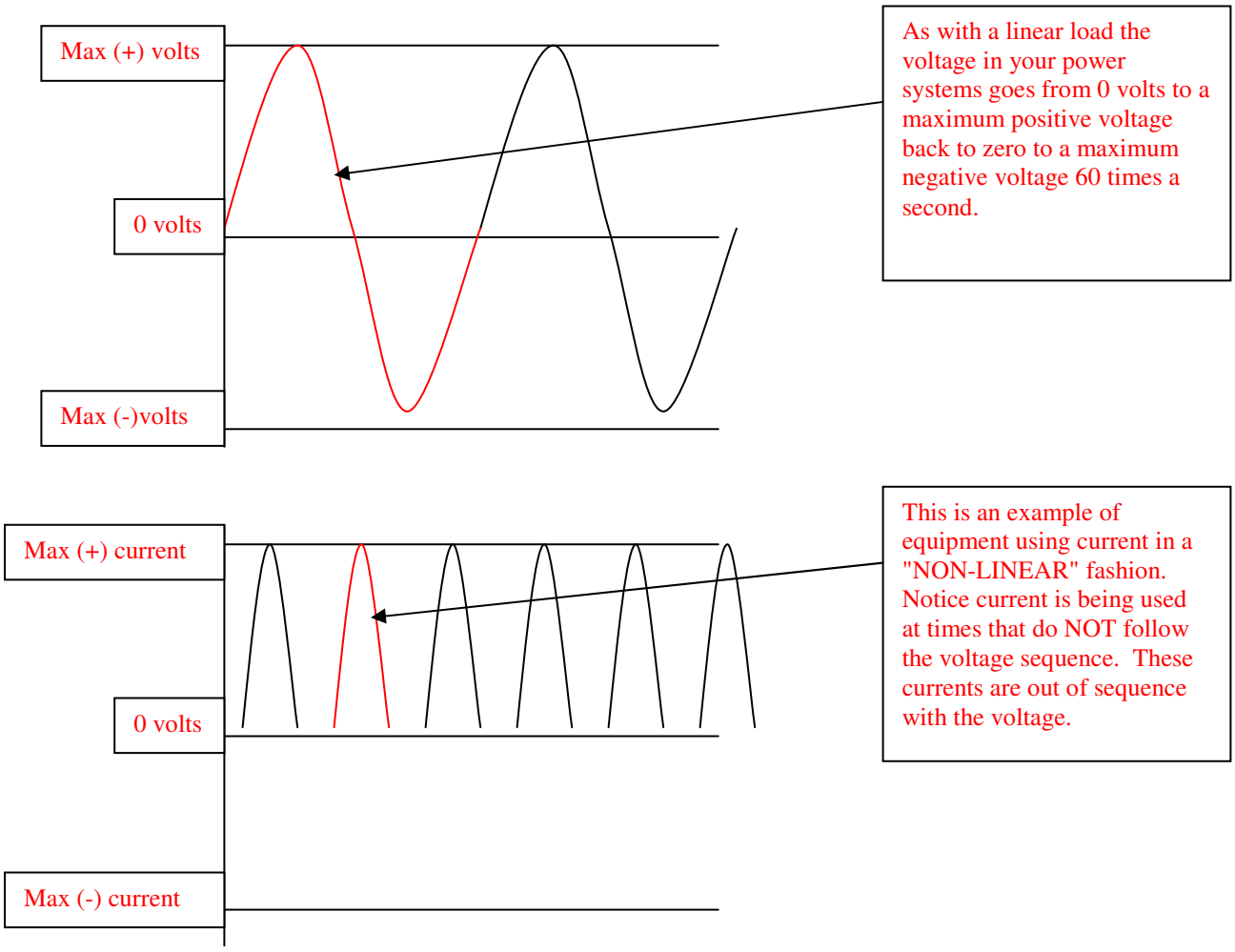
Equipment that uses voltage and current in a linear fashion are called linear loads. Linear loads are, incandescent lighting, motors, and resistive (regular) heaters. Linear loads do NOT generate harmonics.

Since 60 cycles (hertz) is the standard frequency in the United States most of our electrical and electronic equipment has been designed and sized to operate at 60 hertz. We will find out in a moment that harmonic voltages and currents operate at other than 60 hertz. Since most

equipment is designed to operate at 60 hertz and we try and operate it at some other frequency will cause the problems mentioned above.

Equipment that uses voltage and current in a "NON-LINEAR" fashion will create harmonics.

Non-Linear Voltage and Current:



These currents, which are not in sequence with the supply voltage, are called "NON-LINEAR" loads. NON-LINEAR loads generate harmonics. The current flows that contain harmonics do not happen 60 times a second (60 Hertz). The most common damaging harmonic current flows happen at 180, 300, 420, 660, and 780 hertz. Equipment that cause harmonics include, Fluorescent (HID) lighting, Most all electronic equipment (computers, office equipment, modern industrial machines), Variable frequency drives (VFD'S), some Uninterruptible Power Supplies (UPS Systems), and any equipment using switch-mode power supplies. As you can see this

encompasses most of the equipment found in all modern day offices and factories. In fact it is not uncommon to encounter a facility that has almost no linear loads and almost all non-linear harmonic loads.

It is not uncommon to see damage in our power system when we see current flow at frequencies other than 60 hertz. These harmonic currents cause over loading and heat damage to transformers, motors, lighting, switchgear, motor control centers, power correction capacitors, and solid-state equipment. These harmonic currents also flow on your power system neutral. Unless you have a very modern facility that has been designed to have current flow on the neutral you can see damage to your neutral with high harmonic currents. Harmonic currents also cause high frequency electrical noise that can induce (cause) large voltage spikes on your power system ground. This electrical noise on your power system ground can cause damage to sensitive electronic equipment (computers, circuit boards, programmable logic controllers etc.).

How do I know if I have Harmonic currents?

Harmonic currents are easy to detect by using a "TRUE RMS" ammeter. True RMS ammeters can read currents of not only 60 Hertz but other currents at other frequencies. If your meter is not a true RMS type it will only read currents of 60 hertz. These NON-True RMS meters may read only 100 amps, but your system may be operating at 150Amps with currents other than 60 hertz. There are also meters designed to detect the value of harmonic current and also the frequency (180, 300, 420, hertz etc…). If you have "unexplained" damage to equipment, computer or PLC lockups, data corruption, blown fuses, and or circuit breaker tripping. Harmonic currents may be the cause. If you have not had a power quality study at your facility to determine if you have high harmonic current that may be causing damage it is recommended that you do so.

How do you solve a Harmonic System problem?

There are three ways to approach and eliminate problems caused by harmonics in your facility. The first option is to size equipment to withstand the large harmonic neutral currents by using (K-factor) transformers and over sizing neutrals in switchboards panelboards, busway, and all neutral wiring in your facility. The second is to make sure your Transient Voltage Surge Suppression System (TVSS) is an all mode type. The third is to install harmonic filters that trap and eliminate harmonics. Lets look at each one of these approaches.

Oversize Equipment

One of the most harmful effects of harmonics is the damage to transformers in your facility that cannot withstand the heat caused by non-linear harmonic loads. There are transformers built to handle this increased heat, they are called Non Linear K factor transformers. K-Factor transformers are designed to withstand the eddy currents caused by harmonics. Generally they have special sized windings designed for the extra heat generated by eddy currents. They are electrostatic shielded for electrical noise generated by harmonics. They have extra ventilation to help dissipate the heat generated by harmonics. They have oversized neutrals to compensate for the large neutral current caused by harmonics. They are designated by a number that determines

the extent of the harmonics they will encounter. The higher the number the more harmonics they can withstand.

Due the fact that harmonic currents flow on the neutral conductors in your facility it is common practice to oversize the neutral conductors in switchboards, panelboards, busway, and all neutral wiring. All of these products can be sized with 200% neutrals, which means they can carry twice the amount of current of a standard neutral system. It is recommended that you use 200% neutrals where a large number of non-linear equipment is installed. The largest drawback of over sizing is that it does not eliminate harmonics. Without elimination we will still have many power quality problems such as:

- High energy losses do to transformer and equipment overheating due to high harmonic currents.
- Sensitive electronics damage or malfunction due to voltage distortion caused by harmonics.
- Utility surcharges because of harmonics injected into the power grid by your facility.
- Unwanted downtime caused by any or all of the above.

We will discuss further the equipment needed to help eliminate harmonics and the problems caused by them.

Install All Mode Transient Voltage Surge Suppression System (TVSS)

Harmonics induce voltage spikes into your electrical system. These voltage spikes occur throughout your system wiring. Due to these spikes occurring in your wiring conductors it is important that you have an ALL MODE TVSS unit. The term ALL MODE means you have ten modes of protection. A phase to B phase (1), B phase to C phase (2), A phase to C phase (3), A phase to neutral (4), B phase to neutral (5), C phase to neutral (6), A phase to ground (7), B phase to ground (8), C phase to ground (9), and Neutral to Ground (10).

On of the most important modes of protection with a TVSS when harmonics are present is the neutral to ground. With high currents on the neutral caused by harmonics being induced into the ground system at the service entrance it is important to control the voltage spikes between these two locations. Many TVSS units do not have this neutral to ground mode, therefore, make sure your TVSS unit is an all mode type with neutral to ground protection.

Install Harmonic Filter Equipment that trap and eliminate Harmonics.

If your harmonic loads are extremely high and over-sizing alone does not solve problems caused by harmonics you may need to install Harmonic Filter Equipment. This equipment is available as stand alone units or may be incorporated into Power Factor Correction Capacitors, System Transformers, and Line Reactors for Variable Frequency Drives. It is important that you have a good understanding of your electrical system before installing any of the above products, as a condition called harmonic resonance may occur that can cause damage to your system and the components themselves. Please see the paper that discusses Harmonic Cancellation Transformers.

In conclusion

One or all of the above approaches may need to be used to overcome power problems caused by harmonics in your facility. A complete Power and Energy audit may be needed to help gain the necessary information to help you identify and control the effects of harmonics in your facility. Any one or all of the above mentioned equipment might be needed to address the power difficulties you are having in your facility. A close review of the information gained from a Power Quality Study and proper installation of the correct equipment should be considered when implementing a plan of action to solve your facility electrical system troubles.