Harmonics

Power Protection Products, Inc.
Harmonics
White Paper
by Dan Maxcy  |  2018 Update

P3 is the industry's trusted and respected critical power, cooling and energy solutions provider.

877-393-1223  |  www.p3-inc.com
What is a Harmonic? A harmonic is the term used for unwanted and possibly destructive current flow on your facilities conductors (wiring). Harmonic currents can also distort the voltage in your facility that may cause damage to your facility equipment.

**Harmonic problems include:** The overheating and failure of transformers, motors, lighting, switchgear, motor control centers, power correction capacitors, and solid-state equipment (computers, VFD’s, PLC’s etc…). 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 maximum negative amperage 60 times a second.

As with a linear load 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.

**Non-Linear Voltage and Current:**

This is an example of equipment using current in a "NON-LINEAR" fashion. Notice current is being used at times that do NOT follow the voltage sequence. These currents are out of sequence with the voltage.
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 to operate it at some other frequency, problems will occur.

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

**Equipment that uses power in a NON-linear fashion:**

- Computers
- Printers, Copiers & Other Office Equipment
- Fluorescent Lights & Ballast's
- Variable Frequency Drives
- All equipment that uses an AC to DC

©2019 Power Protection Products, Inc. All rights reserved. No part of this publication may be used, photocopied, transmitted, or stored in any retrieval system of any nature, without the written permission of the copyright owner.

www.p3-inc.com

Rev 2019
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. This is done by over sizing neutrals in switchboards panelboards, busway, and all neutral wiring in your facility. It is important to remember, oversizing does NOT eliminate the harmonic problem. It is a "band aid" fix that only masks the issue. The second is to make sure you use Harmonic Mitigating Transformers in your facility. These transformers can eliminate the harmonic currents that cause over loading and heat damage to transformers, motors, lighting, switchgear, motor control centers, power correction capacitors, and solid-state equipment. The third is to install harmonic filters that trap and eliminate harmonics. Let’s look at each one of these approaches.
Oversize Equipment

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.

Install Harmonic Mitigating Transformers

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. These transformers also become very inefficient. These inefficient transformers run hot and can cause loud noise issues due to vibration. The extra heat will increase your utility electrical bills and make a facility pay excessive charges for the electricity used every month.

Installation of Harmonic Mitigating Transformers can eliminate the harmonic currents that cause over loading and heat damage to transformers, motors, lighting, switchgear, motor control centers, power correction capacitors, and solid-state equipment. Harmonic cancellation transformers help reduce harmonics in your power system. The proper installation of Harmonic Cancellation Transformers can have a drastic effect on your power system. They can support up to two times more load than a traditional transformer when high harmonics are present. They can cost up to 50% less to operate due to the energy efficiency gained by reducing harmonics.
Install Harmonic Filter Equipment that traps and eliminates Harmonics.

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.

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.
<table>
<thead>
<tr>
<th>Transformer KVA Sizes</th>
<th>Number of Transformer(s)</th>
<th>This program is owned by MAXWARE</th>
</tr>
</thead>
<tbody>
<tr>
<td>15</td>
<td>0</td>
<td>Written by: Dan Maxcy - 615-321-4883</td>
</tr>
<tr>
<td>30</td>
<td>0</td>
<td>User license: Power Protection Products, Inc.</td>
</tr>
<tr>
<td>45</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>75</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>112.5</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>150</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>225</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>300</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>500</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>

- **Total KVA**: 75
- **System Power Factor**: 0.85
- **System KW**: 63.75
- **Peak Load**: 35%
- **Off Peak load**: 20%
- **Peak load Hours per Day**: 10
- **Off Peak load Hours per Day**: 14
- **Operating Days per Year**: 365

- **System kWh Per Year**: 146,593
- **$ ............... 0.05** kWh Charge
- **$ ............... 5.00** kWh Demand Charge
- **$ ............... 8,668.41** Actual Cost to Run Load Per Year
- **85.0%** Efficiency of Standard Transformer(s)
- **98.0%** Efficiency of EE HMT/ DOE 2016 Transformer(s)
- **3.3** Standard Transformer kW Heat loss at Peak Load
- **1.9** Standard Transformer kW Heat loss at Off Peak Load
- **$ .............. 1,300.26** Cost per year due to heat losses on Standard Transformer(s)

- **$ ............ 9,968.67** Total Electric Bill with Standard Transformer(s) 85.0% Efficient
- **0.4** EE HMT/ DOE 2016 Transformer kW Heat loss at Peak Load
- **0.3** EE HMT/ DOE 2016 Transformer kW Heat loss at Off Peak Load
- **$ ............. 173.37** Cost per year due to heat losses on EE HMT/ DOE 2016 Transformer(s)
- **$ ............. 8,841.77** Total Electric Bill with EE HMT/ DOE 2016 Transformer(s)

- **$ .............. 1,126.89** Total Electric Bill savings per Year with EE HMT/ DOE 2016 Transformers

- **11.3** 98.0% Efficient

- **$ ............ 4,000.00** Cost of Standard Transformer(s)
- **$ ............. 7,500.00** Cost of EE HMT/ DOE 2016 Transformer(s)
- **3.1** Year(s) payback for EE HMT/ DOE 2016 Transformers

- **14** Tons of CO2 Reduction every year
- **46** Tons of Coal Reduction every year
- **110** kgs of SO2 Reduction every year
- **47** kgs of Nox Reduction every year

**EE HMT/ DOE 2018 Transformer Energy Worksheet**

Copyright: MAXWARE 2016. Do Not Duplicate.

You must input information in the colored area:
An Introduction to P3 & PQU

Power Protection Products, Inc. (P3)

P3 is the industry’s trusted and respected advisor for critical power, cooling and energy solutions.

P3 represents some of the leading industry brands and strives to provide the top performing products. We stay on top of industry advances and have designed and built a variety of data center infrastructures, IT expansion projects, and industrial power upgrades.

We believe in providing a stable and secure electrical environment to meet customers’ needs. For more information about our power, cooling, and data center related products & services give us a call or visit our website.

Power Quality University

Providing an educational environment for hands-on training, testing, & evaluation of today’s power quality solutions & equipment.

P3 is “showing you how” with our Power Quality University (PQU) free seminar series. PQU brings real world knowledge into the classrooms. The instructors who teach at PQU are highly qualified professionals and are all experts in the field. Upon completion of a PQU program, students can obtain Continuing Education Credits (CEU’s). PQU is just one more way that Power Protection Products, Inc. is supporting the electrical and data center communities in a positive way.

Learn more at PQU! www.powerqualityuniversity.com

For more information about our products, service plans and support services contact us at:

877-393-1223

Visit our website:

www.p3-inc.com