

# HARMONIC MITIGATING TRANSFORMERS

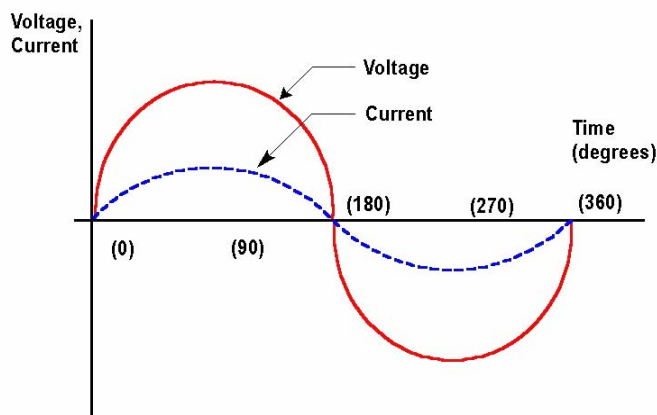
## INTRODUCTION

Harmonics are a misunderstood electrical characteristic and have become an issue of concern in many facilities. No device can completely eliminate harmonics. However, several methods of correcting harmonics in electrical systems thus reducing the likelihood of damage to sensitive electronic equipment are employed. This newsletter highlights one method correcting harmonics: Harmonic Mitigating Transformers.

## WHAT ARE HARMONICS?

Harmonics are defined as electrical voltages and currents with frequencies that are integer multiples of the electrical power frequency. In the United States, the electrical power frequency is 60 Hz. Therefore, the second harmonic is 120Hz, the third harmonic is 180 Hz, the fourth harmonic is 240 Hz and so on.

What does this really mean? To answer this question, let's look at how harmonics are generated. Harmonics are gen-

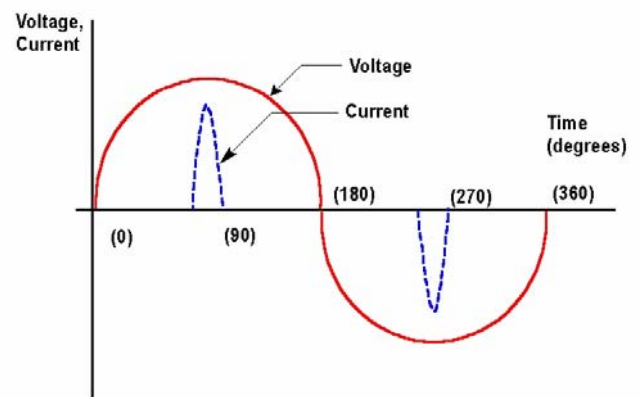


**FIGURE 1 - Clean Electrical Sine Wave**

erated by non-linear loads. These non-linear loads include computers, battery charging systems, fax machines, variable frequency drives, and other electronic equipment. In general, these non-linear loads require DC electric power.

Figure 1 shows a linear load where both the voltage and current wave forms both are sinusoidal. These loads take the electrical power as generated by the electric utility and use the entire voltage and current wave.

Figure 2 is the voltage and current waves from a non-linear load. As the figure shows, this hypothetical load draws current only in short, sub-cycle bursts. Current or voltage usage in this manner will generate harmonics.



**FIGURE 2 - Non-Linear Sine Wave**

## WHY ARE HARMONICS BAD?

As distorted current passes through an electrical distribution system, voltage distortion is then created according to Ohm's Law ( $\text{Volts} = \text{Current} \times \text{Resistance}$ ). Therefore, the

**Harmonics are Corrected using Cutler-Hammer  
Harmonic Mitigating Transformers**

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voltage distortion can travel to all loads connected on a bus or phase. In turn, the distorted voltage can enter electrical equipment and generate a distorted current, again according to Ohm's Law.

These distorted currents can cause transformers and electrical conductors to overheat by generating excess current. Further, electrical currents must be measured using true RMS sensing. An averaging meter measures the distorted current in addition to the linear current. One note, distorted current does no work however the conductors/transformers carry this additional current.

Further, voltage distortion in electric motors excites the windings due to the higher frequencies injected into the stator. In turn, harmonic currents are created. These events cause higher operating temperatures and excessive vibration within the motor leading to additional wear on the motor bearings and shaft.

Electronic equipment is especially sensitive to harmonic effects. Data transmission through a communication or computer network is disrupted, lost, and slowed due to harmonics. Further, damage to electronic is possible when current harmonics are generated.

### TRIPLIN HARMONICS

In commercial buildings, most non-linear (harmonic generating) loads are single phase caused by electronic lighting ballast, copying machines, uninterruptible power supplies and personal computers. Triplen harmonics are those which are the 3<sup>rd</sup>, 9<sup>th</sup>, 15<sup>th</sup> harmonic. These are the most damaging to an electrical system because these triplen harmonic on the A-phase, B-phase and C-phase are in sequence with each other. Meaning, the triplen harmonics present on each of the three phases add together on the neutral rather than cancel each other out. The result can be overheating and failure of electrical components.

### NON-TRIPLIN HARMONICS

Non-Triplen harmonics are either positive sequence or negative sequence. Positive sequence harmonics rotate same direction as the electrical current, typically A-B-C. Conversely, negative sequence harmonics rotate in the opposite direction of the electrical current. Non-triplen harmonics are generated by three-phase loads.

### TRIPLIN MITIGATING TRANSFORMERS

Triplen harmonic are treated using a non-phase shifting (zero sequence) harmonic mitigating transformer. The transformer is able to cancel the triplen harmonics by winding each phase and leg of the transformer is opposite directions. The harmonics then cancel each other out.

However should the phases be unbalance (different loads on each of the three phases), only the balanced portion of the harmonically distorted electrical load is cleaned. The unbalanced portion of a phase load will still contain triplen harmonics. Therefore, balancing the single-phase loads is critical when using mitigating transformers.

### NON-TRIPLIN MITIGATING TRANSFORMERS

Mitigating non-triplen harmonics involves shifting the phases 15° so the harmonics in each phase cancel each other out. Two transformers, one shifting negative 15° and the other shifting 15° positive cause the non-triplen harmonics to cancel. In contrast, a standard K-factor Delta/Wye transformer shifts the phases 30°.

Once again, only the balanced portion of the load will be cleaned of harmonics.

### BENEFITS OF HARMONIC MITIGATION

The use harmonic mitigating transformers adds value to the electrical system and, ultimately, the value of the facility. How? Reducing harmonics saves money. Consider the following points:

- Reduced heating effects caused by harmonic currents.
- Improved power factor.
- Reduced total harmonic voltage distortion.
- Reduced total harmonic current distortion.
- Reduced K-factor of the loads.
- Improved equipment reliability

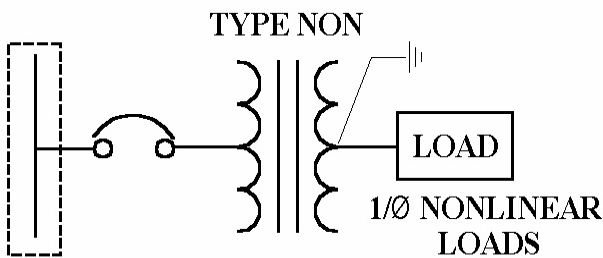
**The bottom line - harmonic current is electrical energy that is purchased and paid for, yet does no work.**

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## HARMONIC MITIGATING TRANSFORMER APPLICATIONS

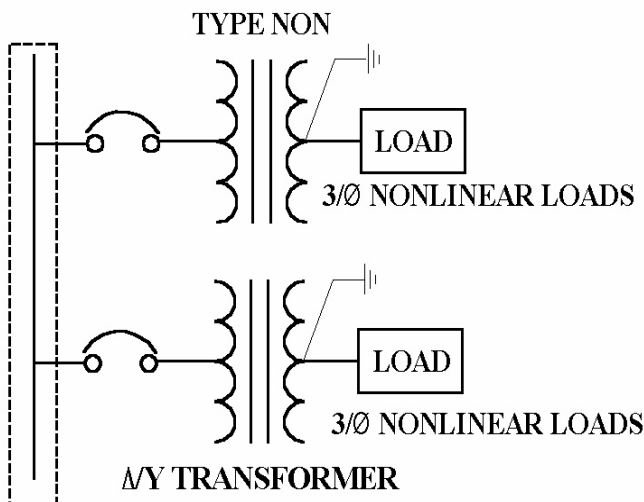
### APPLICATION - 1 $\emptyset$ Triplen Mitigation

This application treats triplen harmonics (3rd, 9th, 15th etc) from heavy concentrations of single-phase, non-linear loads. This is the most common application of Harmonic Mitigating Transformers. Note: a NON Transformer is a Harmonic Mitigating Transformer that does not shift the phase current.



### APPLICATION 2 - 5th, 7th, 17th, 19th Harmonics

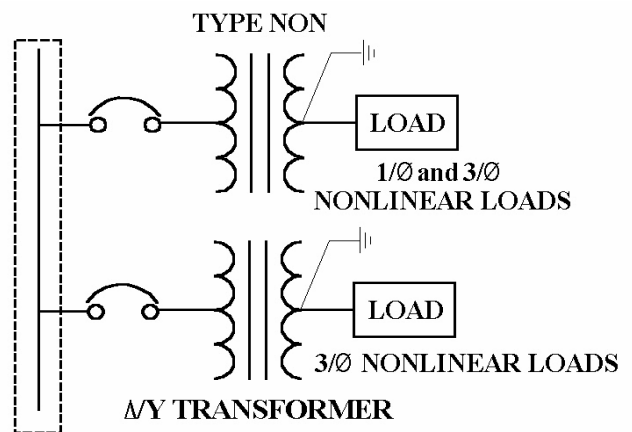
Apply when three-phase non-linear loads are being fed by either a standard or K-factor Delta/Wye transformer, and the loads can be split. The 30° phase shift created between a Type NON transformer and a Delta/Wye transformer provides mitigation of the 5th, 7th, 17th and 19th harmonics.



### APPLICATION 3 - Triplen 5th, 7th, 17th, 19th.

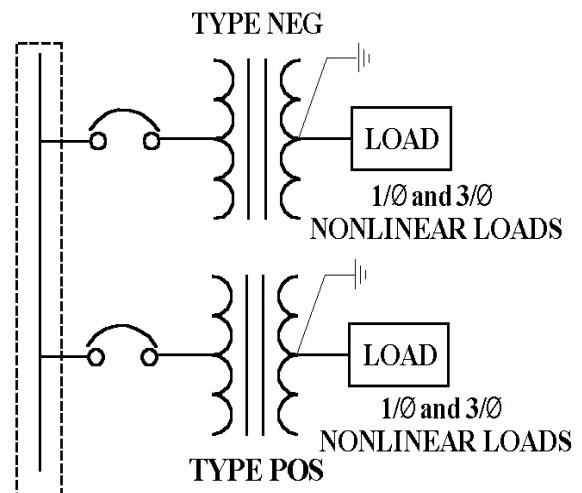
Use this application where the 1 $\emptyset$  and 3 $\emptyset$  non-linear loads can be separated.

The 1 $\emptyset$  non-linear loads must be fed by the NON transformer to mitigate triplen harmonics. The 3PH non-linear load is split and fed by both transformers to cancel 5th, 7th, 17th & 19th at the main feeder. Two transformers are needed - NON and Delta/Wye.



### APPLICATION 4 - Triplen, 5th, 7th, 17th & 19th

The difference between Application 3 and Application 4 is the presence of non-linear, 1 $\emptyset$  loads on both transformers. Triplens will be treated in the transformer secondaries; and 5th, 7th, 17th, & 19th at the main feeder. Two, phase shift transformers, one 15° positive and the other 15° negative, are needed.



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## HISTORY OF EATON CUTLER-HAMMER

Since 1978, **Milwaukee based Cutler-Hammer** has been a business unit division of Eaton Corporation. Eaton Corporation is a diversified \$10B global industrial manufacturer. The Eaton brand name is well known as a leading supplier of highly engineered automotive, truck, and fluid power components and systems. For over 100 years, the Cutler-Hammer brand name has been known as a leading manufacturer of electrical distribution and control equipment.

In 1994, **Westinghouse and Cutler-Hammer were merged** forming the leading electrical service and systems organization including medium voltage gear, low

voltage gear, panelboards, motor control centers, variable frequency drives, soft starts, and control components (indicating lights, pushbuttons, selector switches).

Cutler-Hammer also includes a dedicated, factory trained service organization (not subcontractors) for turn-key electrical service. Cutler-Hammer Engineering System and Service (**CHES**) provides retrofit, power quality, project management and start-up services for both new construction and existing systems.

The traditional “C -H Square” logo will give way to the new Eaton | Cutler-Hammer brand logo.



## COGENERATING POWERPLANT SWITCHGEAR and CONTROL

Cutler-Hammer was awarded the system for a new power plant located in Wisconsin. The project includes the following electrical systems:

- **Medium Voltage Vacuum Clad Switchgear**
- **Low Voltage Power Switchgear**
- **Medium Voltage Vacuum Motor Starters**
- **Low Voltage Motor Control Centers**

The low voltage motor control centers are the new Cutler-Hammer Intelligent Technologies (IT). The IT features 24VDC control and Devicenet communication.

All of the electrical distribution and control gear will communicate to a central, distributed control system. The distribution system includes protective relaying and metering.



See the specially designed Eaton Electrical Consulting Engineer Web Site at <http://www.eatonelectrical.com/crp>