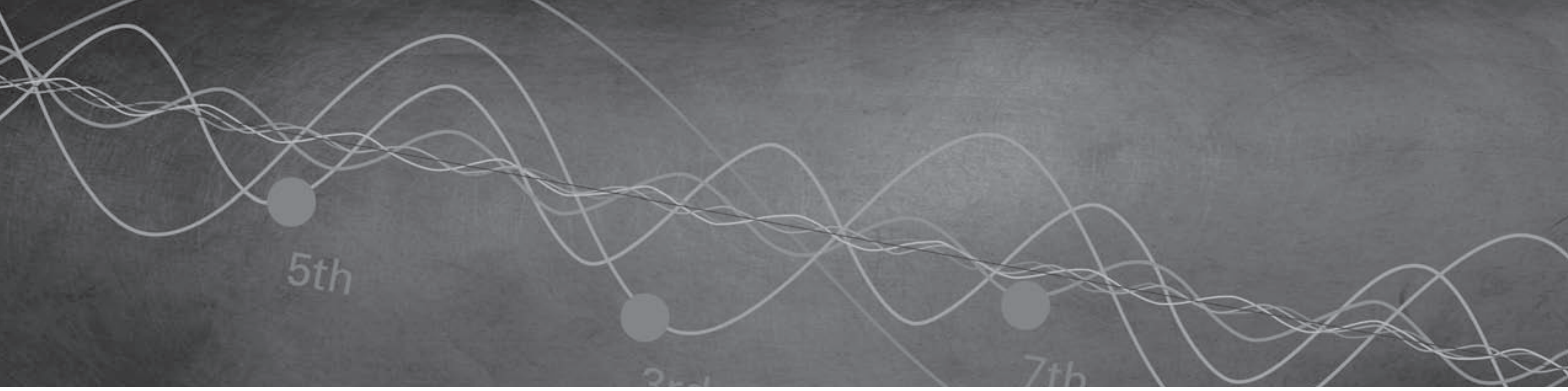
Harmonic mitigating transformers

Energy savings through harmonic mitigation

Powering Business Worldwide

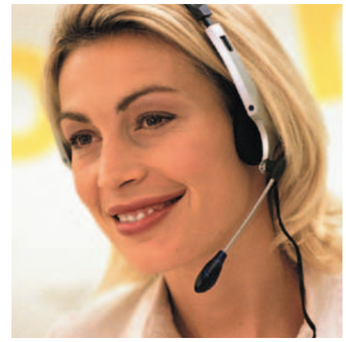


Harmonic mitigating transformers

Today's issues and needs

Eaton's Harmonic Mitigating Transformer (HMT)

As our world becomes even more dependent on electrical and electronic equipment, there is an increased likelihood that operations will experience the negative effects of harmonic distortion. The productivity and efficiency gains achieved from increasingly sophisticated pieces of equipment have a drawback: increased harmonic distortion in the electrical distribution system. Eaton's harmonic mitigating transformers (HMTs) are a leading solution to help eliminate these harmful harmonics and improve your system reliability.



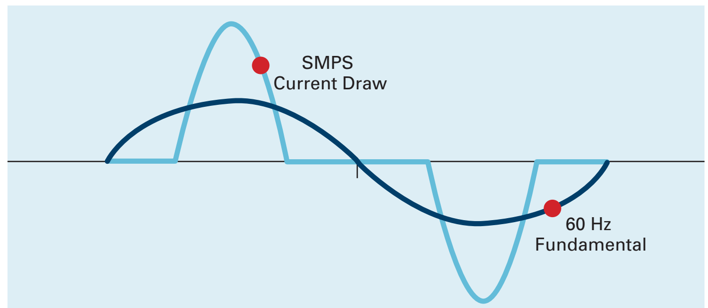
What are harmonics?

An understanding of how harmonics are generated and how they flow in a power system aids in the understanding of how HMTs can provide harmonic mitigation. Electronic equipment requires DC voltage to operate. Rectifiers and capacitors are used to convert AC voltage to DC voltage within the equipment. These devices are frequently referred to as switch mode power supplies (SMPS). As the capacitors charge and discharge during this conversion, the capacitor draws current in pulses, not at a continuous rate. This irregular current demand, as depicted in **Graph A**, distorts the linear 60 Hz sine wave. As a result, these types of loads are commonly referred to as non-sinusoidal, or nonlinear.

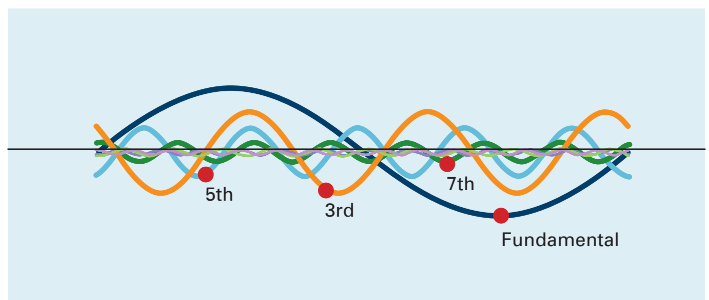
As shown in **Graph A** and **Graph B**, the waveform created by the nonlinear source is actually the mathematical sum of several sine waves, each with a different frequency and magnitude. Each of these individual waveforms is called a harmonic, and is identified by its frequency relative to the fundamental frequency, 60 Hz. In other words, each individual harmonic is identified by a number, which is the number of complete cycles the specific harmonic goes through in a single 60 Hz cycle.

In **Graph B**, the fundamental frequency is 60 Hz. The fundamental frequency is assigned the harmonic number of 1, and is the benchmark for all other harmonic numbering. The fundamental, 60 Hz sine wave completes 60 full cycles in one second. The 3rd harmonic completes three full cycles in the time it takes the fundamental to complete just one cycle, or 180 cycles per second. Likewise, the 5th harmonic completes five full cycles in the time it takes the fundamental harmonic to complete a single cycle, which equates to 300 Hz (cycles per second). Odd multiples of the 3rd harmonic (3rd, 9th,15th, 21st and so on) are commonly referred to as triplen harmonics.

The proliferation of electronic equipment (including computers, fax machines, copiers, electronic ballasts, office equipment, cash registers, slot machines, electronic monitoring devices, video games and medical diagnostic equipment) is what makes single-phase devices the most common source of harmonics. These devices generate a typical waveform, shown in **Graph A**, and have a harmonic profile as shown in the table at right.



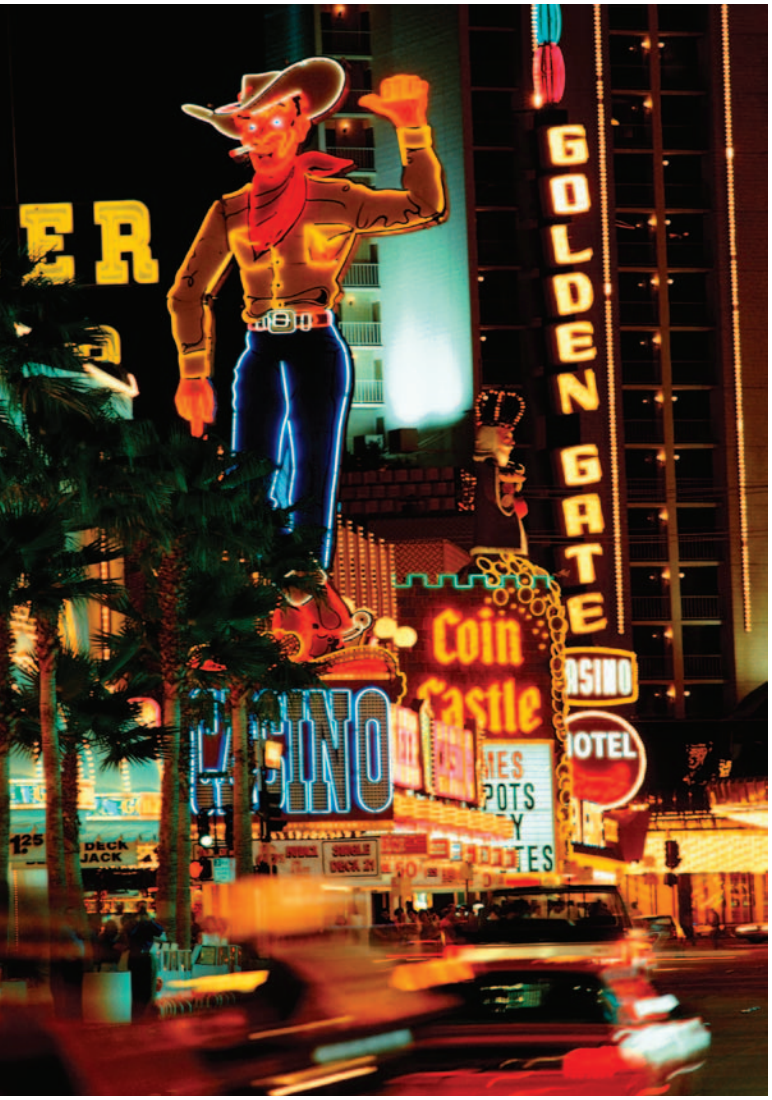
Graph A. Typical Waveform of Single-Phase Devices



Graph B. Components of a Nonlinear Waveform

Typical Harmonic Profile of Single-Phase SMPS

Harmonic	Magnitude
1	1.000
3	0.810
5	0.606
7	0.370
9	0.157
11	0.024
13	0.063
15	0.079



What problems do harmonics cause?

The distorted current waveform that is created by nonlinear loads can cause many problems in an electrical distribution system. While all buildings with modern load have harmonic content, the real question to ask is, "Are the harmonic levels at a point where they can cause misoperation and disruption to the load within the building?" It is a myth that K-factor rated transformers provide harmonic treatment. Rather they are oversized to withstand the destructive effects of the additional heat generated by harmonic currents in the transformer's windings. Their larger size means that more watts will be wasted (as compared with a standard transformer) to feed the same size load.

In many instances, the harmful effects of harmonics are too severe, and simply tolerating them is not an acceptable option. Harmonic currents can cause excessive heating in distribution transformers. This additional heat not only reduces the life expectancy of a transformer, it also reduces its usable capacity. This additional heat waste means a higher than necessary electric bill for the building owner to feed the nonlinear load.

An important characteristic of harmonics is that they are transmitted upstream from the load, to the transformer's secondary windings, through the primary windings of the transformer, back to the service entrance, and eventually to the utility lines.

Harmonic currents flowing upstream from nonlinear loads, through the system impedance of cables and transformers, create harmonic voltage distortion. When linear loads, like motors, are subjected to harmonic voltage distortion, they will draw a nonlinear harmonic current. As with distribution transformers, harmonic currents cause increased heating, due to iron and copper losses, in motors and generators. This increased heating can reduce the life of the motor, as well as the motor's efficiency. In electrical cables, harmonic currents may also create increased heating, which can lead to premature aging of the electrical insulation. Nuisance tripping of the circuit breakers protecting the cable may also occur. Communications equipment and data processing equipment are especially susceptible to the harmful effects of harmonics because they rely on a nearly perfect sinusoidal input. This equipment may malfunction, or even fail, when installed in systems that are rich in harmonics.

PROBLEMS CAUSED BY HARMONICS

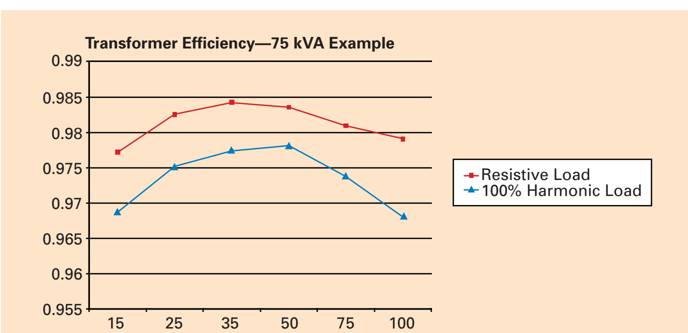
- Excessive heating in distribution transformers
- Increased cooling load on buildings
- Increased heating in motors and generators
- Increased heating in cables
- Nuisance tripping of breakers
- Malfunction or failure of communications and data processing equipment

The costs associated with downtime resulting from the malfunction or failure of electrical or electronic equipment can be staggering. These costs can easily surpass thousands, if not millions, of dollars per hour in lost production or lost productivity. In addition to these well-defined costs associated with the most catastrophic of harmonic effects, there are many less quantitative costs that are often overlooked when evaluating the need for harmonic mitigation. The increased heating caused by harmonics in motors and transformers increases the cooling requirements in air-conditioned areas. The same increases in heating result in increased maintenance costs and more frequent equipment replacement in order to avoid failures that could shut down a building for a period of time.

What do HMTs do?

HMTs are an economical solution in the battle against the harmful effects of harmonics. HMTs are highly reliable passive devices; they don't have any moving parts and they are typically energized 24 hours a day, seven days a week, 365 days a year. This means that they are always "on the job" treating harmonics, regardless of the level of load they are serving at a given point in time. Whenever the HMT is energized, it will provide harmonic treatment.

Harmonic mitigating transformers are commonly referred to as "phase-shifting" transformers. The HMT offering from Eaton has three-wire connected primary windings and four-wire connected secondary windings. The fundamental changes to the magnetics of the transformer winding allow a transformer to be designed in a wide variety of different phase-shifts (–15°, 0°, +15°, 30°). In standard delta-wye transformers, including K-factor rated transformers, triplen harmonics are passed from the secondary windings into the primary delta windings, where they flow and cause substantial additional watt loss. In HMTs, the electromagnetic flux cancellation created by the zigzag winding configuration prevents 3rd and other triplen harmonics from being transmitted into the primary delta winding. Harmonic treatment is provided entirely by electromagnetic flux cancellation; no filters, capacitors, or other such devices are used. It is important to remember that the harmonic currents still flow to the secondary windings.



Energy Bill Savings

Benefits of installing HMTs

In addition to improved system reliability and reduced maintenance costs, HMTs also have excellent energy-saving characteristics. With the cost of electricity continuing to increase around the world, there is an ever-increasing interest in energy-efficient products. In many facilities, the cost of electricity is the second largest expense, eclipsed only by salaries and wages. As mentioned, distribution transformers are typically energized 24 hours a day, 7 days a week, 365 days a year.

Transformers consume energy even when they are lightly loaded or not loaded at all. Significant energy savings may be attained if the no-load losses of a transformer are reduced. NEMA® Standard TP-1 addresses this issue by requiring high efficiency levels when a transformer is loaded at 35 percent of its full capacity. However, this standard applies to linear load profiles only, and tests to validate compliance with NEMA TP-1 are performed using linear loads. In actual applications, the growing presence of electronic devices creates nonlinear load profiles. Nonlinear loads cause the losses in distribution transformers to increase, thereby reducing their realized efficiency. Therefore, NEMA TP-1 efficiency compliance may not be a true indication of the efficiency of a transformer exposed to nonlinear loads. Though only a measure of linear load efficiency, the efficiency standards set forth in NEMA Standard TP-1 are met by Eaton's family of MTIs. Because HMTs are intended to be installed in systems that contain high levels of nonlinear loads, Eaton's family of HMTs is designed to meet the NEMA TP-1 efficiency levels when applied to nonlinear load profiles with 100 percent harmonic distortion, across a broad range of load levels, not just the 35 percent load level used in NEMA TP-1. These energy savings are realized over the entire life of the transformer.

Markets for HMTs

Educational facilities

Harmonic-generating devices exist in all regions of the country. Many educational facilities are found to be excellent candidates for HMTs. The peace of mind and security of knowing that our schools' electrical distribution systems are being protected from the harmful effects of harmonics is important to people who manage, maintain, teach and learn in these facilities. Grade schools across the country have added computers to their classrooms. Similarly, colleges and universities are taking advantage of the benefits of the computer, and students are using computers in their dormitories. Today, the average college student brings a staggering 18 electrical loads to his or her dorm room—most of which are nonlinear loads. Many colleges also have laboratories and studying facilities that contain an ever-increasing number of electronic devices. An electrical failure resulting from excessive harmonics may result in the loss or corruption of research data that took hours or weeks or even years to accumulate. Such failures may also necessitate faculty and students being evacuated from classrooms or dormitories.

Commercial facilities

In commercial office buildings, customer service call-centers, insurance companies, government offices, and the office space of manufacturing facilities, the presence of computers, printers, copying machines, and other electronic office equipment, along with fluorescent lighting ballasts, creates an environment that is full of harmonics. The productivity losses that can result from the loss of power in these environments can be significant. Electronic data files specific to certain customers or operations can also become corrupted or lost as a result of the ill effects of harmonics.

Retail facilities

Retail facilities such as electronic and appliance stores, as well as malls, plazas and grocery stores, typically make use of electronic cash registers and fluorescent lighting. Lost sales resulting from a blackout traced back to harmonics can add up quickly. The installation of an HMT can help prevent these losses.

Medical facilities

Medical facilities are also ideal locations for HMTs. Most modern diagnostic and analysis equipment is electronic. Excessive harmonics could cause personal records or medical test data to be corrupted or destroyed. Recovery of this information would be very costly.

Gaming industry

Harmonic-generating devices are so common that the list of potential applications is growing daily. In more recent applications, HMTs can be beneficial in casinos, racetracks and off-track-gaming parlors. In these facilities, not only are the gaming losses that can result from a power failure of concern, but just imagine the security issues and risks involved.

In all of the aforementioned applications, the energy savings that can result from the application of an HMT can be substantial. The normal life of a distribution transformer is recognized as being 20 years or more. In many installations, the life-cycle energy savings alone offer a quick payback on the investment. Once the initial investment is recovered, the energy savings can be realized for years and years to come.

Product selection

As with other harmonic mitigation techniques, in order to obtain the maximum benefit offered by the HMT solution, the harmonic content in the electrical distribution system should be identified. There is a wide variety of meters available on the market that can assist in determining which harmonics exist in a system. The Eaton Electrical Services & Systems (EESS) team has years of experience in identifying harmonics and their sources. With field service engineers located throughout the country, they are readily available to perform this on-site testing.

If the precise harmonic profile of a load is not known, it is still possible to select HMTs that will provide the benefits of harmonic treatment. By knowing the general characteristics of the loads, HMTs can be effectively selected. The basic question that needs to be answered is, "Are the loads that the transformer is feeding single-phase, or are they three-phase?" This question applies to the ultimate loads, not the intermediate loads such as a panelboard. Once this question has been answered, the selection of an HMT can commence.

In all of the aforementioned applications, the energy savings that can result from the application of an HMT can be substantial. The normal life of a distribution transformer is recognized as being 20 years or greater. In many installations, the life-cycle energy savings alone offer a quick payback on the investment.

Once the initial investment is recovered, the energy savings can be realized for years and years to come.

As shown in **Graph A** on **Page 3**, the harmonic profile of single-phase electronic devices is dominated by the 3rd and other triplen harmonics. Triplen harmonics are treated in the secondary windings of a single HMT transformer.

Three-phase loads (and, to an extent, single-phase loads) generate a harmonic profile that has predominantly 5th and 7th harmonics. Cancellation of 5th, 7th, 17th and 19th harmonic currents is attained through the use of two or more transformers with a 30° phase shift between them. These harmonic currents pass through the transformers and are cancelled at the first common (or shared) electrical bus. A few examples of a common electrical bus include a panelboard, a switchboard and a bus duct. Any electrical equipment that feeds all of the transformers used in a harmonic cancellation scheme is likely to be a common bus. Possible phase-shift combinations that could be used to treat these higher order harmonic currents would be the pairing of 0° and 30° transformers, or the pairing of –15° and +15° transformers. It isn't necessary for these transformers to be in the same room, or on the same floor, as long as they are fed from a common point—a common electrical bus.

In instances where a transformer is feeding a mix of single-phase and three-phase loads, pairs of harmonic mitigating transformers with a 30° phase shift between them offer treatment of triplen harmonics, as well as 5th, 7th, 17th and 19th harmonics. The 30° phase shift between the transformers treats 5th, 7th, 17th and 19th harmonics at the common electrical bus, while at the same time, the secondary zigzag windings treat triplen harmonics at the transformer.

Harmonic Mitigating Transformer Catalog Numbering System

X 48 M 28F 30 TCUEE NON

Primary Voltage ❶
29 = 208 Vac
48 = 480 Vac
60 = 600 Vac

Tap Arrangement
M = 2 at +2.5%, 4 at –2.5%
D = 2 at +2.5%, 2 at –2.5%

Secondary Voltage ❶
28 = 208/120 Vac
47 = 480/277 Vac

Temperature Rise
F = 115°C
T = 150°C
B = 80°C

kVA Rating
15 = 15
30 = 30
45 = 45
75 = 75
12 = 112.5
49 = 150
22 = 225
33 = 300

Modifications ❶ ❷	
T	= Single thermal sensor (190°C)
TT	= Two thermal sensors (190°C and 175°C)
X	= 50/60 Hz
CU	= Copper windings (standard)
EE	= Energy efficient (standard)
SS	= Stainless steel enclosure
P1	= 40 kA per phase TVSS installed on transformer primary
P2	= 80 kA per phase TVSS installed on transformer primary
P3	= 160 kA per phase TVSS installed on transformer primary
S1	= 40 kA per phase TVSS installed on transformer secondary
S2	= 80 kA per phase TVSS installed on transformer secondary (standard)
S3	= 160 kA per phase TVSS installed on transformer secondary
P1P	= 40 kA per phase TVSS installed on transformer primary with indicating light
P2P	= 80 kA per phase TVSS installed on transformer primary with indicating light
P3P	= 60 kA per phase TVSS installed on transformer primary with indicating light
S1P	= 40 kA per phase TVSS installed on transformer secondary with indicating light
S2P	= 80 kA per phase TVSS installed on transformer secondary with indicating light
S3P	= 160 kA per phase TVSS installed on transformer secondary with indicating light

Phase Shift
NON = 0°
THR = 30°
POS = +15°
NEG = –15°

❶ The most common ratings are shown. Contact Eaton for availability of additional ratings.

❷ When TVSS option is chosen, case and frame sizes may be increased—check with factory for final case dimensions.

Pre-installed TVSS option

The application and use of the Eaton HMT is normally in "electrically sensitive" areas that usually incorporate other power quality devices to ensure proper and prolonged operation of the equipment. This usually includes a transient voltage surge suppression (TVSS) device to protect against both internal and external high-voltage transient spikes. The Eaton HMT is available with a variety of TVSS protection sizes (40, 80, or 160 kA per phase) and can be factory-installed either on the primary or the secondary of the transformer. Some benefits of ordering this factory-installed option are:

- Helps to limit field wiring errors
- Minimizes installation costs
- Provides a single provider of the equipment
- An optional indicator light can be mounted on the front of the transformer enclosure to provide a visual indication if the TVSS fails to function when the transformer is energized

Low-sound (LS) option

The physical location of the electrical dry-type transformer in today's design has a tendency to move it closer and closer to the building occupants, meaning that its audible noise can start to become an issue. In the past, the transformer was in its own electrical room and audible noise was not as much of a concern. To help meet these needs, the Eaton HMT offers the option of a low-sound (LS) characteristic, which means that the audible noise produced by the transformer will be –3 dB lower than the industry standard (NEMA ST20) levels. As audible noise is measured on a logarithmic scale, every –3 dB of change represents a lowering of about half the perceived noise coming from the transformer. (Note that sound levels are measured in a specialized sound room, not at the installation.)

These low-noise transformers are ideal for noise-sensitive installations such as schools, hospitals, libraries and offices. Proper installation procedures should be used to achieve maximum benefit.

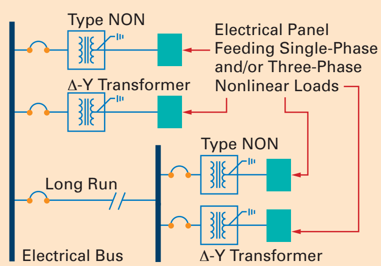
Warranty

Eaton's family of HMTs carries a 10-year, pro-rated warranty against failure.

Application information

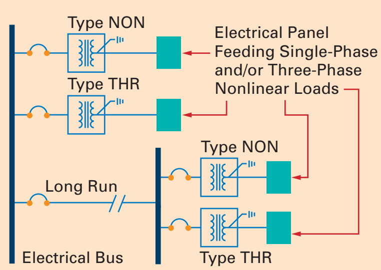
The closer an HMT can be located to the load, the greater the benefits of harmonic treatment. Installation of a large-capacity HMT at the service entrance of a large building would certainly provide some harmonic treatment. However, installation of several smaller-rated HMTs, perhaps one or more on each floor of a building, provides greater benefits that will be noticed throughout the facility and on the energy bill. This complements the cost efficiencies that can be gained by distributing higher voltages through smaller cables to the point where a safer, lower voltage is needed to operate equipment.

When connecting the loads to the transformer, it is important to remember that the balanced portion of the harmonic loads will be treated. When considering the triplen harmonics that are treated in the secondary windings, each phase should be balanced and the harmonic profile of the loads should be as similar as possible to achieve the maximum harmonic treatment. When treating 5th, 7th and higher order harmonic by using multiple transformers, the transformers and loading should be identical, but because we're adding in "negatives" (through the change of the phase shift angles), the impact on the system will be much greater than using just standard, K-rated, or TP-1 transformers (which will all have similar phase shifts). For example, two 75 kVA HMTs can be "paired" with a single 150 kVA HMT to provide maximum harmonic performance. In real-world situations, it is nearly impossible to have perfectly matched loads. However, the benefits of treating harmonics, even in situations in which the loads are unbalanced, far outweigh not treating them at all.



When a delta-wye transformer exists in an electrical distribution system, the addition of a Type NON transformer offers an economical solution for treating harmonic currents. The 30° phase shift created between a Type NON harmonic mitigating transformer and a delta-wye transformer (standard transformer or K-Factor transformer) provides treatment of 5th, 7th, 17th and 19th harmonic currents. These harmonic currents are cancelled in the common electrical bus that feeds the transformers. Additionally, triplen (3rd, 9th, 15th and so on) harmonic currents generated by the loads connected to the Type NON transformer will be treated in the secondary windings of the Type NON transformer due to its low zero sequence impedance 1. When using two or more transformers to treat harmonics, it is better that the load be split equally between the transformers to receive the maximum benefit.

Typical Application of Type NON Transformer with a Standard Delta-Wye Transformer



When you're searching for an optimum harmonic correction solution in an electrical distribution system, the combination of a Type NON and a Type THR transformer offers a great solution. The 30° phase shift created between Type NON and Type THR harmonic mitigating transformers provides treatment of 5th, 7th, 17th and 19th harmonic currents. These harmonic currents are cancelled in the common electrical bus that feeds the transformers. Additionally, triplen (3rd, 9th, 15th and so on) harmonic currents generated by the loads will be treated in the secondary windings of HMTs. This will ensure that these currents will not circulate in the primary of the transformer creating additional heat, voltage distortion and wasted energy loss. When using two or more transformers to treat harmonics, it is better that the load be split equally between the transformers to receive the maximum benefit.

Optimum Application of Type NON and Type THR Transformers

Type Non-Harmonic Mitigating Transformer Selection Information

	Full Capacity Taps			°C	Dimensions in Inches (mm)					Wiring	Weathershield	
kVA	FCAN	FCBN	Type	Temp. Rise	Height	Width	Depth	Wt. in Lbs (kg)	Frame	Diagram Number	Catalog Number	Style Number
480V to 208/120V, Shielded, Copper Windings, NEMA TP-1 Energy Efficient, 0-Degree Phase Shift (No Thermal Sensor)												
15	2 at +2.5%	4 at –2.5%	DT-3	150	30.00 (762.0)	20.13 (511.2)	14.13 (358.8)	320 (145)	FR910A	200X	**WS31**	**X48M28T15CUEENON**
30	2 at +2.5%	4 at –2.5%	DT-3	150	30.00 (762.0)	23.00 (584.2)	16.50 (419.1)	370 (168)	FR912B	200X	**WS38**	**X48M28T30CUEENON**
45	2 at +2.5%	4 at –2.5%	DT-3	150	39.25 (996.9)	29.00 (736.6)	22.00 (558.8)	550 (250)	FR914D	200X	**WS39**	**X48M28T45CUEENON**
75	2 at +2.5%	4 at –2.5%	DT-3	150	46.63 (1184.3)	28.00 (711.2)	23.00 (584.2)	925 (420)	FR916A	200X	**WS19**	**X48M28T75CUEENON**
112.5	2 at +2.5%	4 at –2.5%	DT-3	150	56.25 (1428.8)	31.25 (793.7)	24.25 (615.9)	1600 (726)	FR917	200X	**WS34**	**X48M28T12CUEENON**
150	2 at +2.5%	4 at –2.5%	DT-3	150	62.25 (1581.2)	31.25 (793.7)	30.25 (768.3)	2170 (986)	FR918A	200X	**WS34**	**X48M28T49CUEENON**
225	2 at +2.5%	4 at –2.5%	DT-3	150	75.00 (1905.0)	44.50 (1130.3)	36.00 (914.4)	3100 (1409)	FR919X	201X	**WS35**	**X48M28T22CUEENON**
300	2 at +2.5%	2 at –2.5%	DT-3	150	75.00 (1905.0)	44.50 (1130.3)	36.00 (914.4)	3300 (1500)	FR919X	201X	**WS35**	**X48M28T33CUEENON**
500	2 at +2.5%	4 at –2.5%	DT-3	150	75.00 (1905.0)	44.50 (1130.3)	36.00 (914.4)	4800 (2179)	FR920X	201X	**WS35**	**X48M28T55CUEENON**
15	2 at +2.5%	4 at –2.5%	DT-3	115	30.00 (762.0)	20.13 (511.2)	14.13 (358.8)	320 (145)	FR910A	200X	**WS31**	**X48M28F15CUEENON**
30	2 at +2.5%	4 at –2.5%	DT-3	115	30.00 (762.0)	23.00 (584.2)	16.50 (419.1)	370 (168)	FR912B	200X	**WS38**	**X48M28F30CUEENON**
45	2 at +2.5%	4 at –2.5%	DT-3	115	39.25 (996.9)	29.00 (736.6)	22.00 (558.8)	550 (250)	FR914D	200X	**WS39**	**X48M28F45CUEENON**
75	2 at +2.5%	4 at –2.5%	DT-3	115	46.63 (1184.3)	28.00 (711.2)	23.00 (584.2)	925 (420)	FR916A	200X	**WS19**	**X48M28F75CUEENON**
112.5	2 at +2.5%	4 at –2.5%	DT-3	115	56.25 (1428.8)	31.25 (793.7)	24.25 (615.9)	1600 (726)	FR917	200X	**WS34**	**X48M28F12CUEENON**
150	2 at +2.5%	4 at –2.5%	DT-3	115	62.25 (1581.2)	31.25 (793.7)	30.25 (768.3)	2170 (986)	FR918A	200X	**WS34**	**X48M28F49CUEENON**
225	2 at +2.5%	4 at –2.5%	DT-3	115	75.00 (1905.0)	44.50 (1130.3)	36.00 (914.4)	3600 (1634)	FR919X	201X	**WS35**	**X48M28F22CUEENON**
300	2 at +2.5%	4 at –2.5%	DT-3	115	75.00 (1905.0)	44.50 (1130.3)	36.00 (914.4)	3500 (1589)	FR919X	201X	**WS35**	**X48M28F33CUEENON**
500	2 at +2.5%	4 at –2.5%	DT-3	115	75.00 (1905.0)	44.50 (1130.3)	36.00 (914.4)	4800 (2179)	FR920X	201X	**WS35**	**X48M28F55CUEENON**

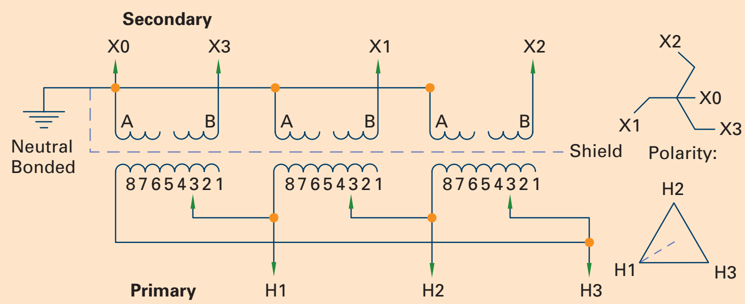
Note: Information could change at any time. Please contact Eaton for details.

Type THR Harmonic Mitigating Transformer Selection Information

	Full Capacity Taps			°C	Dimensions in Inches (mm)					Wiring	Weathershield	
kVA	FCAN	FCBN	Type	Temp. Rise	Height	Width	Depth	Wt. in Lbs (kg)	Frame	Diagram Number	Catalog Number	Style Number
480V to 208/120V, Shielded, Copper Windings, NEMA TP-1 Energy Efficient, 30-Degree Phase Shift (No Thermal Sensor)												
15	2 at +2.5%	4 at –2.5%	DT-3	150	30.00 (762.0)	20.13 (511.2)	14.13 (358.8)	320 (145)	FR910A	203X	**WS31**	**X48M28T15CUEETHR**
30	2 at +2.5%	4 at –2.5%	DT-3	150	30.00 (762.0)	23.00 (584.2)	16.50 (419.1)	370 (168)	FR912B	203X	**WS38**	**X48M28T30CUEETHR**
45	2 at +2.5%	4 at –2.5%	DT-3	150	39.25 (996.9)	29.00 (736.6)	22.00 (558.8)	550 (250)	FR914D	203X	**WS39**	**X48M28T45CUEETHR**
75	2 at +2.5%	4 at –2.5%	DT-3	150	46.63 (1184.3)	28.00 (711.2)	23.00 (584.2)	925 (420)	FR916A	203X	**WS19**	**X48M28T75CUEETHR**
112.5	2 at +2.5%	4 at –2.5%	DT-3	150	56.25 (1428.8)	31.25 (793.7)	24.25 (615.9)	1600 (726)	FR917	203X	**WS34**	**X48M28T12CUEETHR**
150	2 at +2.5%	4 at –2.5%	DT-3	150	62.25 (1581.2)	31.25 (793.7)	30.25 (768.3)	2170 (986)	FR918A	203X	**WS34**	**X48M28T49CUEETHR**
225	2 at +2.5%	4 at –2.5%	DT-3	150	75.00 (1905.0)	44.50 (1130.3)	36.00 (914.4)	3100 (1409)	FR919X	203X	**WS35**	**X48M28T22CUEETHR**
300	2 at +2.5%	2 at –2.5%	DT-3	150	75.00 (1905.0)	44.50 (1130.3)	36.00 (914.4)	3300 (1500)	FR919X	203X	**WS35**	**X48M28T33CUEETHR**
500	2 at +2.5%	4 at –2.5%	DT-3	150	75.00 (1905.0)	44.50 (1130.3)	36.00 (914.4)	4800 (2179)	FR920X	203X	**WS35**	**X48M28T55CUEETHR**
15	2 at +2.5%	4 at –2.5%	DT-3	115	30.00 (762.0)	20.13 (511.2)	14.13 (358.8)	320 (145)	FR910A	203X	**WS31**	**X48M28F15CUEETHR**
30	2 at +2.5%	4 at –2.5%	DT-3	115	30.00 (762.0)	23.00 (584.2)	16.50 (419.1)	370 (168)	FR912B	203X	**WS38**	**X48M28F30CUEETHR**
45	2 at +2.5%	4 at –2.5%	DT-3	115	39.25 (996.9)	29.00 (736.6)	22.00 (558.8)	550 (250)	FR914D	203X	**WS39**	**X48M28F45CUEETHR**
75	2 at +2.5%	4 at –2.5%	DT-3	115	46.63 (1184.3)	28.00 (711.2)	23.00 (584.2)	925 (420)	FR916A	203X	**WS19**	**X48M28F75CUEETHR**
112.5	2 at +2.5%	4 at –2.5%	DT-3	115	56.25 (1428.8)	31.25 (793.7)	24.25 (615.9)	1600 (726)	FR917	203X	**WS34**	**X48M28F12CUEETHR**
150	2 at +2.5%	4 at –2.5%	DT-3	115	62.25 (1581.2)	31.25 (793.7)	30.25 (768.3)	2170 (986)	FR918A	203X	**WS34**	**X48M28F49CUEETHR**
225	2 at +2.5%	4 at –2.5%	DT-3	115	75.00 (1905.0)	44.50 (1130.3)	36.00 (914.4)	3600 (1634)	FR919X	203X	**WS35**	**X48M28F22CUEETHR**
300	2 at +2.5%	4 at –2.5%	DT-3	115	75.00 (1905.0)	44.50 (1130.3)	36.00 (914.4)	3500 (1589)	FR919X	203X	**WS35**	**X48M28F33CUEETHR**
500	2 at +2.5%	4 at –2.5%	DT-3	115	75.00 (1905.0)	44.50 (1130.3)	36.00 (914.4)	4800 (2179)	FR920X	203X	**WS35**	**X48M28F55CUEETHR**

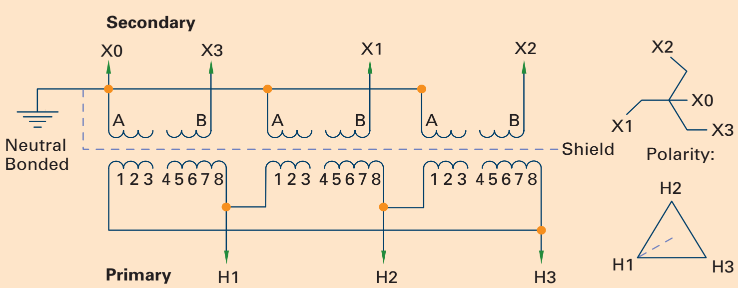
Note: Information could change at any time. Please contact Eaton for details.

Volts	Tap
504	1
492	2
480	3
468	4
456	5
444	6
432	7



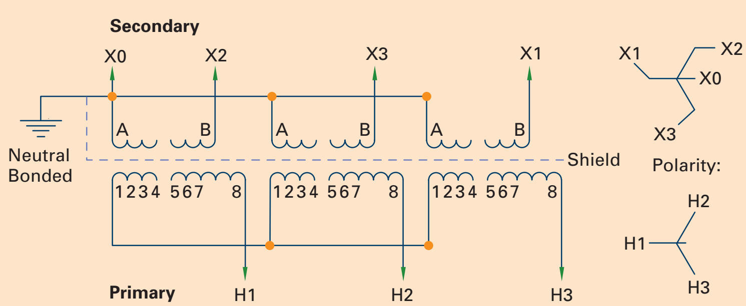
Wiring Diagram 200X—For HMT-NON Sized 15–150 kVA

Volts	Tap
504	4 to 5
492	4 to 6
480	4 to 7
468	3 to 6
456	3 to 7
444	2 to 6
432	2 to 7



Wiring Diagram 201X—For HMT-NON Sized 225–500 kVA

Volts	Tap
504	4 to 5
492	4 to 6
480	4 to 7
468	3 to 6
456	3 to 7
444	2 to 6
432	2 to 7



Wiring Diagram 203X—For HMT-THR Sized 15–500 kVA

Eaton is dedicated to ensuring that reliable, efficient and safe power is available when it's needed most. With unparalleled knowledge of electrical power management across industries, experts at Eaton deliver customized, integrated solutions to solve our customers' most critical challenges.

Our focus is on delivering the right solution for the application. But, decision makers demand more than just innovative products. They turn to Eaton for an unwavering commitment to personal support that makes customer success a top priority. For more information, **visit www.eaton.com/electrical**.

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