

Harmonic mitigating transformers



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Product/application description

Harmonic mitigating transformers

Transformers have been, and will continue to be, an essential component of modern electrical distribution systems. As the world becomes more dependent upon electric and electronic equipment, electrical distribution systems are exposed to increasing levels of harmonics. Harmonic currents cause additional heating, which may cause transformers, generators, and conductors to become overloaded. Excessive heat is one of the major reasons that distribution transformers and conductors fail prematurely.

Eaton's family of harmonic mitigating transformers is an effective solution for reducing harmonic currents.

Treatment of harmonics offers many benefits. A reduction in the amount of heat generated by harmonic currents lowers maintenance costs and equipment replacement costs, and allows the transformer to operate at a lower temperature, which eliminates overheating and excessive operating temperatures. The reduced operating temperature may result in lower cooling costs in the area where the transformer is installed. The reduction in heat generated by harmonic currents also allows the full capacity of a transformer to be used. There is no need to de-rate the transformer below the nameplate capacity. Eaton's entire family of harmonic mitigating transformers is ENERGY STAR® labeled, a sign that they are in the upper tier of energy-efficient products.

Determining the source of harmonic distortion is normally a difficult task. As a complete power quality resource, Eaton offers several products and services to assist in identifying and measuring sources of harmonic distortion. Once the harmonic profile has been determined, the solution may be simple. Installation of harmonic mitigating transformers can be a relatively easy solution to mitigating specific harmonic problems.

There are several factors that need to be considered when determining which solution will be the best to solve a specific power quality problem. Harmonic mitigating transformers are one such solution that Eaton has to offer.

Features, benefits, and functions

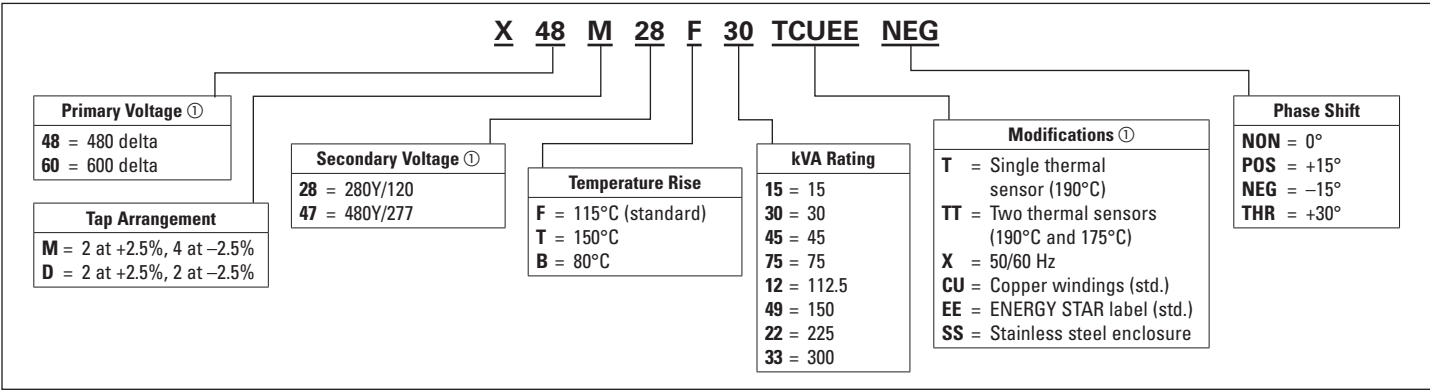
- 480V delta primary and 208Y/120V secondary standard rating; additional voltage combinations are also available
- Electrostatic shield for attenuation of high-frequency noise
- 115°C temperature rise standard; 80°C and 150°C are optional
- Copper windings and terminals as standard; aluminum is optional
- Meet or exceed NEMA® TP-1-1996 energy-efficiency levels
- 200% rated neutral
- 220°C Insulation system
- Performance validated by a nationally recognized independent testing facility
- Eliminate circulating harmonic currents in primary windings of transformers
- Low zero sequence impedance and zero sequence reactance
- Enclosures are NEMA 2 drip-proof. The addition of optional weathershields makes the enclosure NEMA 3R rainproof
- Harmonic cancellation via electromagnetic flux cancellation; filters, capacitors, or other such devices are not used
- Variety of phase-shift options available to treat specific harmonics in a system
- Helps meet IEEE® 519 harmonic limits

Standards and certifications

- UL® listed and labeled
- Comply with applicable NEMA, ANSI, and IEEE standards

Product selection

Table 1. Catalog Numbering System



① The most common ratings are shown. Contact Eaton for availability of additional ratings.

Table 2. Type NON Harmonic Mitigating Transformers ①

Style Number	kVA	Full Capacity Taps		Type	°C Temperature Rise	Approximate Weight Lbs (kg)	Frame Number	Wiring Diagram Number	Weathershield Style Number
		FCAN	FCBN						
480 Delta Volts to 208Y/120V									
X48M28F15CUEENON	15	2 at +2.5%	4 at −2.5%	DT-3	115	362 (164)	912B	200X	WS38
X48M28F30CUEENON	30	2 at +2.5%	4 at −2.5%	DT-3	115	434 (197)	912B	200X	WS38
X48M28F45CUEENON	45	2 at +2.5%	4 at −2.5%	DT-3	115	627 (284)	915D	200X	WS39
X48M28F75CUEENON	75	2 at +2.5%	4 at −2.5%	DT-3	115	926 (420)	916A	200X	WS19
X48M28F12CUEENON	112.5	2 at +2.5%	4 at −2.5%	DT-3	115	1628 (738)	917	200X	WS34
X48M28F49CUEENON	150	2 at +2.5%	4 at −2.5%	DT-3	115	2001 (908)	918A	200X	WS34
X48M28F22CUEENON	225	2 at +2.5%	4 at −2.5%	DT-3	115	3596 (1631)	919X	201X	WS35
X48M28F33CUEENON	300	2 at +2.5%	4 at −2.5%	DT-3	115	3891 (1765)	919X	201X	WS35

① Dimensions and weights subject to change.

Table 3. Type POS Harmonic Mitigating Transformers ①

Style Number	kVA	Full Capacity Taps		Type	°C Temperature Rise	Approximate Weight Lbs (kg)	Frame Number	Wiring Diagram Number	Weathershield Style Number
		FCAN	FCBN						
480 Delta Volts to 208Y/120V									
X48M28F15CUEEPOS	15	2 at +2.5%	4 at −2.5%	DT-3	115	353 (160)	912B	200X	WS38
X48M28F30CUEEPOS	30	2 at +2.5%	4 at −2.5%	DT-3	115	450 (204)	912B	200X	WS38
X48M28F45CUEEPOS	45	2 at +2.5%	4 at −2.5%	DT-3	115	627 (284)	915D	200X	WS39
X48M28F75CUEEPOS	75	2 at +2.5%	4 at −2.5%	DT-3	115	900 (408)	916A	200X	WS19
X48M28F12CUEEPOS	112.5	2 at +2.5%	4 at −2.5%	DT-3	115	1628 (738)	917	200X	WS34
X48M28F49CUEEPOS	150	2 at +2.5%	4 at −2.5%	DT-3	115	1800 (817)	918A	200X	WS34
X48M28F22CUEEPOS	225	2 at +2.5%	4 at −2.5%	DT-3	115	3000 (1361)	919X	201X	WS35
X48M28F33CUEEPOS	300	2 at +2.5%	4 at −2.5%	DT-3	115	3500 (1588)	919X	201X	WS35

① Dimensions and weights subject to change.

Table 4. Type NEG Harmonic Mitigating Transformers ①

Style Number	kVA	Full Capacity Taps		Type	°C Temperature Rise	Approximate Weight Lbs (kg)	Frame Number	Wiring Diagram Number	Weathershield Style Number
		FCAN	FCBN						
480 Delta Volts to 208Y/120V									
X48M28F15CUEENEG	15	2 at +2.5%	4 at −2.5%	DT-3	115	353 (160)	912B	200X	WS38
X48M28F30CUEENEG	30	2 at +2.5%	4 at −2.5%	DT-3	115	450 (204)	912B	200X	WS38
X48M28F45CUEENEG	45	2 at +2.5%	4 at −2.5%	DT-3	115	627 (284)	915D	200X	WS39
X48M28F75CUEENEG	75	2 at +2.5%	4 at −2.5%	DT-3	115	900 (408)	916A	200X	WS19
X48M28F12CUEENEG	112.5	2 at +2.5%	4 at −2.5%	DT-3	115	1628 (738)	917	200X	WS34
X48M28F49CUEENEG	150	2 at +2.5%	4 at −2.5%	DT-3	115	1800 (817)	918A	200X	WS34
X48M28F22CUEENEG	225	2 at +2.5%	4 at −2.5%	DT-3	115	3000 (1361)	919X	201X	WS35
X48M28F33CUEENEG	300	2 at +2.5%	4 at −2.5%	DT-3	115	3500 (1588)	919X	201X	WS35

① Dimensions and weights subject to change.

Technical data

Dimensions

Table 5. Dimensions

Frame Number	A Inches (mm)	B Inches (mm)	C Inches (mm)	D Inches (mm)	E Inches (mm)
912B	30.00 (762.0)	23.00 (584.2)	16.50 (419.1)	21.04 (534.4)	11.00 (279.4)
915D	39.18 (995.2)	29.00 (736.6)	22.00 (558.8)	26.92 (683.8)	16.00 (406.4)
916A	46.63 (1184.4)	28.00 (711.2)	23.00 (584.2)	26.29 (667.8)	18.82 (478.0)
917	56.25 (1428.8)	31.25 (793.7)	24.25 (616.0)	29.50 (749.3)	20.00 (508.0)
918A	62.25 (1581.2)	31.25 (793.8)	30.25 (768.4)	29.50 (749.3)	26.00 (660.4)
919X	75.00 (1905.0)	44.50 (1130.3)	35.75 (908.1)	40.75 (1035.1)	24.00 (609.6)

① Dimensions and weights subject to change.

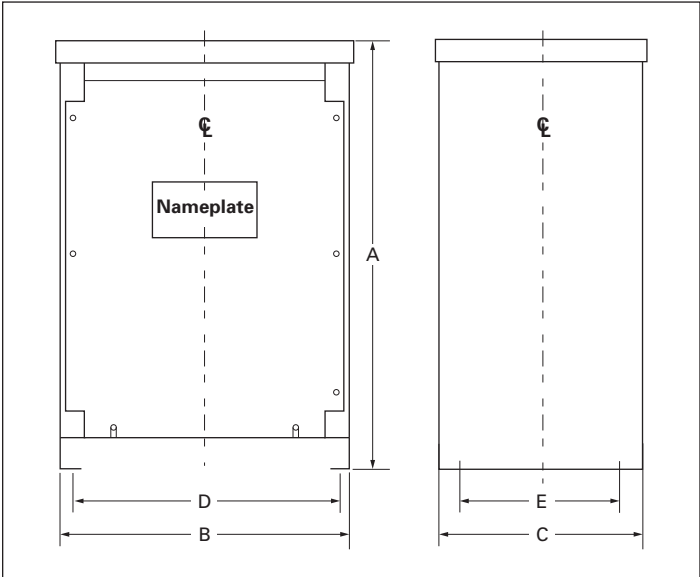


Figure 1. Harmonic Mitigating Transformer Dimensions

Wiring Diagrams

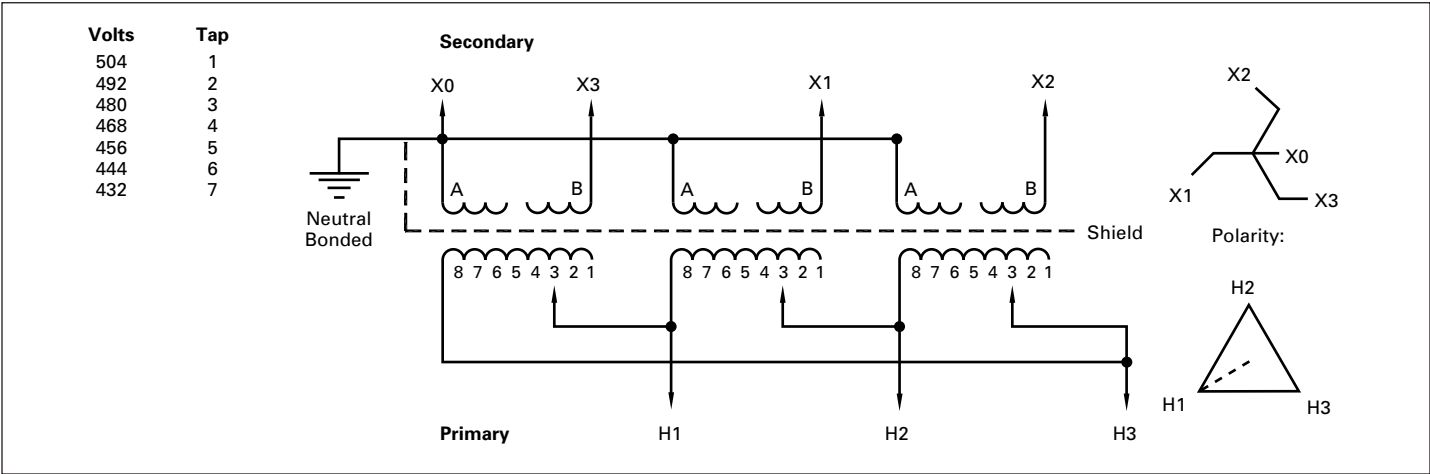


Figure 2. Wiring Diagram 200X

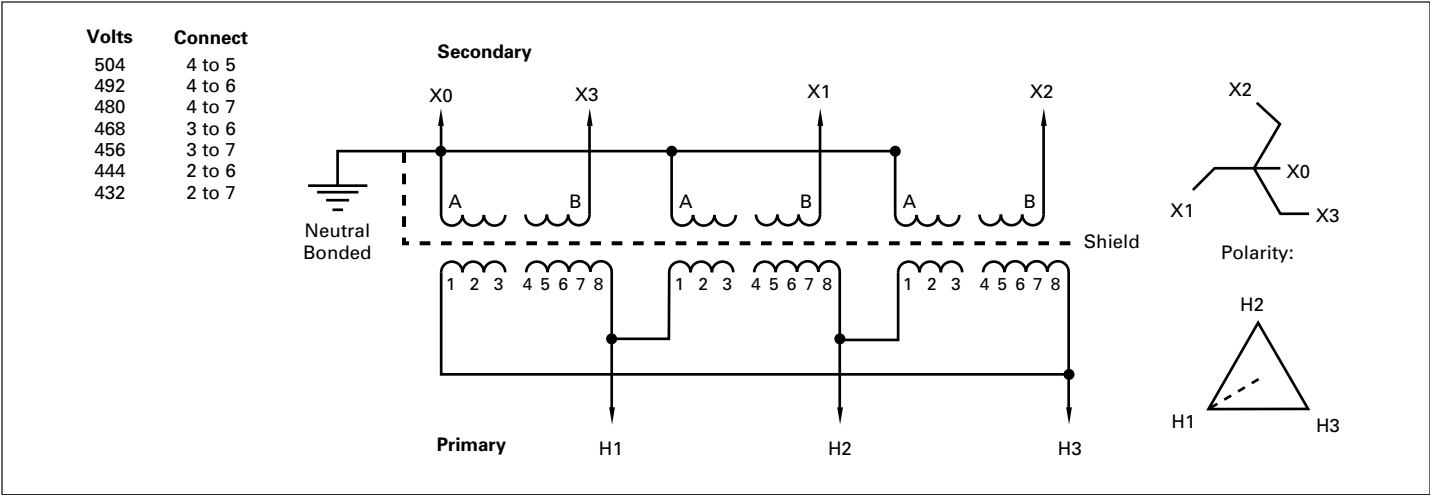


Figure 3. Wiring Diagram 201X

Application information

Single-phase nonlinear loads, such as computers, fax machines, printers, and other electronic equipment, generate significant amounts of triplen (3rd, 9th, 15th, and so on), 5th, and 7th harmonic currents. Similarly, phase-to-phase and 6-pulse nonlinear loads generate significant amounts of 5th and 7th harmonic currents. Twelve-pulse loads generate primarily 11th and 13th harmonic currents. These harmonic currents have various effects on components of an electrical distribution system. Triplen harmonic currents may result in neutral current as much as 1.7 times the phase current. Harmonic currents also cause circulating currents in the primary windings of delta-wye connected transformers. Harmonic currents flow through the impedance in an electrical distribution system (primarily conductors and transformers), and create voltage and current distortion.

The Eaton family of harmonic mitigating transformers is designed to have very low zero sequence impedance and zero sequence reactance.

In a standard delta-wye transformer or K-factor transformer, zero sequence currents flow through the secondary wye winding and are coupled into the primary delta winding where they are trapped. These zero sequence currents can cause excessive heating and voltage distortion. Eaton's harmonic mitigating transformers treat the 3rd and other triplen harmonics in the secondary winding of the transformer. Treatment of 5th, 7th, and additional higher level harmonic currents can be accomplished by introducing the appropriate phase-shift between multiple transformers connected to a common bus in an electrical distribution system. When treating these higher level harmonic currents, it is important to balance the load between the transformers, as only the balanced portion of the load is treated. Voltage distortion is normally greatest at the point where the equipment is connected to the distribution system. Therefore, to attain maximum benefit, harmonic mitigating transformers should be installed as close as possible to the panels they feed.

In addition to the benefits mentioned above, Eaton's family of harmonic mitigating transformers is also designed to meet NEMA TP-1 and ENERGY STAR efficiency levels. Additionally, these harmonic mitigating transformers have an efficiency of at least 98% under nonlinear load conditions. This means you can attain reduced energy consumption regardless of the load profile.

The harmonic mitigating transformer family consists of three types of transformers. Type NON is a delta-zigzag transformer with a 0° phase-shift. Type NEG and Type POS are also delta-zigzag transformers; however, their phase-shift is -15° and +15° respectively.

Harmonic treatment is not limited to those shown in **Figure 4**, **Figure 5**, and **Figure 6**. However, the three examples shown are the most common applications. By combining Type NON, Type POS, Type NEG, and standard delta-wye transformers, higher level harmonic currents can also be effectively treated.

Installation of a Type NON transformer provides an effective treatment of triplen (3rd, 9th, 15th, and so on) harmonic currents that are generated by loads connected to the transformer. Triplen harmonic currents are treated in the secondary windings of the transformer due to the transformer's low zero sequence impedance. Type NON transformers do not need to be used in a combination with other transformers to treat triplen harmonic currents. A single Type NON transformer may be installed, or multiple units can be applied.

Type NON transformers are an ideal solution for treating triplen harmonics generated by personal computers, printers, fax machines, and other office equipment, as well as by single-phase electronic ballasts, and single-phase electronic testing or monitoring devices.

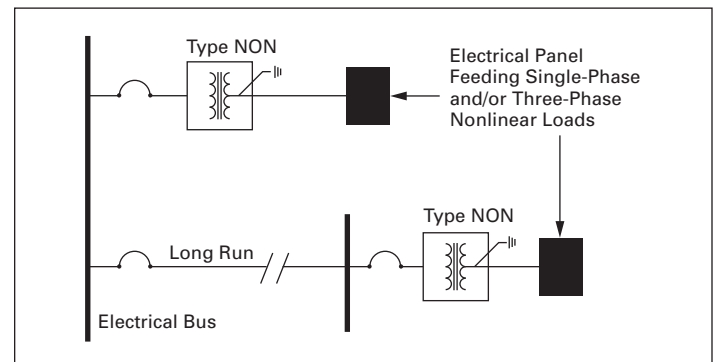


Figure 4. Typical Application of Type NON Transformer

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 canceled 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. When using two or more transformers to treat harmonics, it is important that the load be split equally between the transformers because only the balanced portion of the load will be treated. Similarly, the impedance values of the transformers should be identical to receive the maximum benefit.

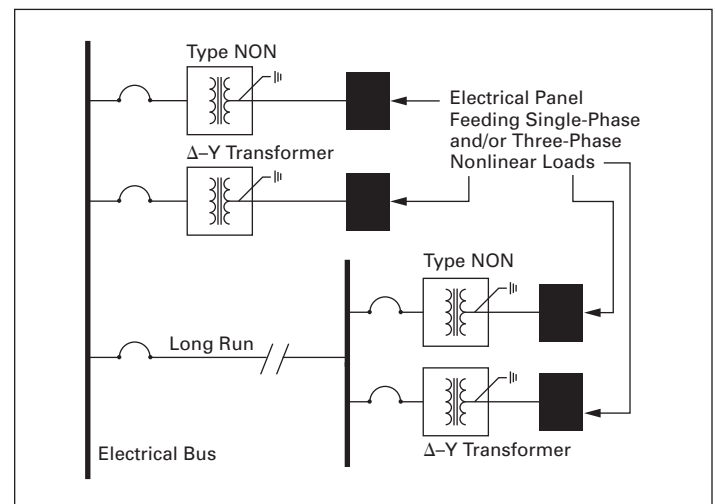


Figure 5. Typical Application of Type NON Transformer with a Standard Delta-Wye Transformer

The combination of a Type POS (+15° phase-shift) transformer and a Type NEG (−15° phase-shift) transformer effectively treats 5th, 7th, 17th, and 19th harmonic currents. These harmonic currents are canceled 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 these transformers will be treated in their secondary windings due to their low zero sequence impedance. When using two or more transformers to treat harmonics, it is important that the load be split equally between the transformers because only the balanced portion of the load will be treated. Similarly, the impedance values of the transformers should be identical to receive the maximum benefit. When using Type NEG transformers and Type POS transformers of the same ratings, this is less of an issue than it may be when using pairs of 0° and 30° phase-shift transformers. The impedance of similarly sized Type NEG and Type POS transformers is nearly identical by design.

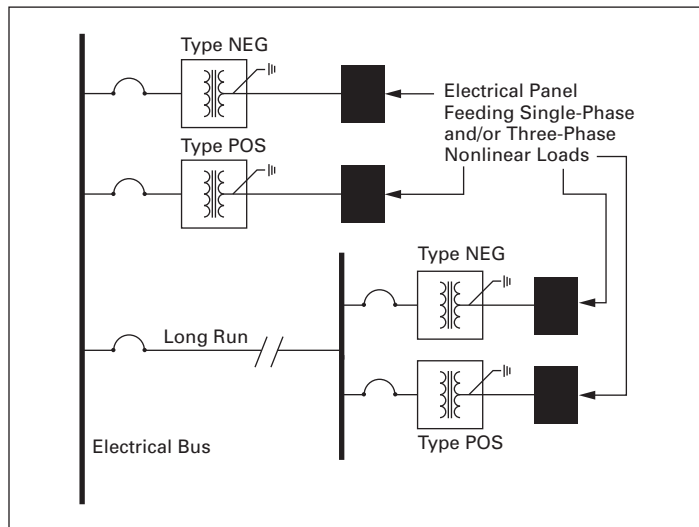


Figure 6. Typical Application of Type NEG and Type POS Transformers

Typical specification

Part 1 General

1.01 Scope

- A. The Contractor shall furnish and install three-phase dry-type harmonic mitigating transformers of the two-winding, self-cooled type as specified herein, and as shown on the contract drawings.

1.02 Related Sections

1.03 References

- A. The transformers and all components shall be designed, manufactured, and tested in accordance with the latest applicable standards of ANSI, NEMA, and UL.

1.04 Submittals—for review/approval

- A. The following information shall be submitted to the Engineer:
 1. Outline dimensions and weights.
 2. Transformer ratings, including:
 - a. kVA
 - b. Primary and secondary voltage
 - c. Taps
 - d. Design impedance
 - e. Insulation class and temperature rise
 - f. Sound level
 3. Product data sheets.

1.05 Submittals—for construction

- A. The following information shall be submitted for record purposes.
 1. Final as-built drawings and information for items listed in paragraph 1.04.
 2. Connection diagrams.
 3. Installation information.
 4. Seismic certification and equipment anchorage details.
- B. The final (as-built) drawings shall include the same drawings as the construction drawings and shall incorporate all changes made during the manufacturing process.

1.06 Qualifications

- A. For the equipment specified herein, the manufacturer shall be ISO® 9001 or 9002 certified, and ISO 14001 certified.
- B. The manufacturer of this equipment shall have produced similar electrical equipment for a minimum period of five (5) years.
- C. Transformers shall be suitable for and certified to meet all applicable seismic requirements of the International Building Code (IBC), Uniform Building Code® (UBC), California Building Code (CBC), or BOCA® National Building Code. Guidelines for the installation consistent with these requirements shall be provided by the transformer manufacturer and be based upon testing of representative equipment. The tests shall fully envelop the applicable response spectrum for all equipment natural frequencies up to at least 35 Hz.
- D. The following minimum mounting and installation guidelines shall be met, unless specifically modified by the above referenced standards.
 - 1. The Contractor shall provide equipment anchorage details, coordinated with the equipment mounting provision, prepared and stamped by a licensed civil engineer in the state. Mounting recommendations shall be provided by the manufacturer based upon approved shake table tests used to verify the seismic design of the equipment.
 - 2. The transformer manufacturer shall certify that the equipment can withstand, that is, function, following the seismic event, including both vertical and lateral required response spectra as specified in above codes.
 - 3. The equipment manufacturer shall document the requirements necessary for proper seismic mounting of the equipment. Seismic qualification shall be considered achieved when the capability of the equipment meets or exceeds the specified response spectra.

1.07 Regulatory requirements

- A. All transformers shall be UL Listed and bear the UL label.

1.08 Delivery, storage, and handling

- A. Equipment shall be handled and stored in accordance with manufacturer's instructions. One (1) copy of these instructions shall be included with the equipment at time of shipment.

1.09 Operation and maintenance manuals

- A. Equipment operation and maintenance manuals shall be provided with each assembly shipped, and shall include instruction leaflets and instruction bulletins for the complete assembly and each major component.

Part 2 Products**2.01 Manufacturers**

- A. Eaton's Business
- B. _____
- C. _____

The listing of specific manufacturers above does not imply acceptance of their products that do not meet the specified ratings, features, and functions. Manufacturers listed above are not relieved from meeting these specifications in their entirety. Products in compliance with the specification and manufactured by others not named will be considered only if pre-approved by the Engineer ten days prior to bid date.

2.02 Ratings

- A. kVA and voltage ratings shall be as shown on the drawings.
- B. Transformers shall be designed for continuous operation at rated kVA, for 24-hours-a-day, 365-days-a-year operation, with normal life expectancy as defined in ANSI C57.96.
- C. Transformer sound levels shall not exceed the following ANSI and NEMA levels for self-cooled ratings:

0 to	9 kVA	40 db
10 to	50 kVA	45 db
51 to	150 kVA	50 db
151 to	300 kVA	55 db
301 to	500 kVA	60 db
501 to	700 kVA	62 db
701 to	1000 kVA	64 db
1001 to	1500 kVA	65 db

2.03 Construction

- A. Insulation systems
 - 1. Transformers shall be insulated with a UL recognized 220°C insulation system. Winding temperature rise shall not exceed 115°C.
 - 2. Required performance shall be obtained without exceeding the above indicated temperature rise in a 40°C maximum ambient, and a 24-hour average ambient of 30°C.
 - 3. All insulation materials shall be flame-retardant and shall not support combustion as defined in ASTM Standard Test Method D635.
- B. Core and coil assemblies
 - 1. Transformer core shall be constructed of high-grade electrical steel with high magnetic permeability, and low hysteresis and eddy current losses. Maximum magnetic flux densities shall be substantially below the saturation point. The transformer core volume shall allow efficient transformer operation at 10% above the nominal tap voltage. The core laminations shall be tightly clamped and compressed.
 - 2. The core and coil assembly shall be impregnated with non-hygroscopic, thermosetting varnish and cured to reduce hot spots and seal out moisture. The assembly shall be installed on vibration-absorbing pads.
 - 3. Primary and secondary windings shall be wound of electrical grade copper (aluminum) with continuous wound construction. All terminals and bussing shall be copper (aluminum).
 - 4. Neutral conductor shall be copper (aluminum) and rated to carry 200% of normal phase current.
- C. Taps
 - 1. Three-phase transformers rated 15 through 500 kVA shall be provided with six 2-1/2% taps; two above and four below rated primary voltage.
- D. Electrostatic shielding
 - 1. Harmonic mitigating transformers shall be provided with a single full-width electrostatic shield consisting of a single turn of aluminum placed between the primary and secondary winding and grounded.

E. Energy efficiency

1. Transformers are to be low loss type with minimum efficiencies per NEMA TP-1-1996 when operated at 35% of full load capacity. Manufacturer shall be an ENERGY STAR Partner, and transformers shall bear the ENERGY STAR label.
2. Nonlinear load efficiency shall be a minimum of 98% at performance validation load profile identified below.

F. Performance validation

1. Harmonic mitigating transformers shall be designed to meet the efficiency levels outlined above. Harmonic performance and energy efficiency shall have been validated by a nationally recognized independent testing facility. Testing to be conducted using three single-phase 120V load banks with a personal computer harmonic profile (100% current THD) at a minimum of 35% of transformer's nameplate kVA.

G. Harmonic treatment

1. Harmonic mitigating transformers shall have low zero sequence impedance and low zero sequence reactance.
2. Triplen harmonics shall be treated in the secondary windings through flux cancellation and not coupled into the primary winding.
3. Fundamental current imbalance shall be reduced on the primary when compared to the secondary load measurements.
4. Harmonic treatment shall be through electromagnetic means. No filters, capacitors, or other such devices shall be used to treat harmonics.
5. Fifth and 7th harmonic currents shall be treated through the pairing of phase-shifted transformers such that these harmonic currents subtract at the common bus feeding the transformers.

H. Thermal sensors

1. When required, provide transformers with a thermal sensor set at 190°C. Provide a second thermal sensor set at 175°C when required. Thermal sensor(s) shall be factory-installed in the center coil of the transformer and factory-wired to a terminal strip. Thermal sensors shall consist of a set of dry contacts.

2.04 Wiring/Terminations

- A. Recommended external cable shall be rated 75°C for ventilated designs. Connectors should be selected on the basis of the type and cable size used to wire the specific transformer.

2.05 Enclosure

- A. The enclosure shall be made of heavy-gauge steel and shall be finished using a continuous process of degreasing, cleaning, and phosphatizing, followed by electrostatic deposition of a polymer polyester powder coating and baking. Enclosure shall be ANSI 61.
- B. All transformers shall be equipped with a wiring compartment suitable for conduit entry and large enough to allow convenient wiring.
- C. The maximum temperature of the enclosure shall not exceed 90°C.
- D. The core of the transformer shall be visibly grounded to the enclosure.
- E. Enclosure construction shall be ventilated, NEMA 2, drip-proof, with lifting provisions. All ventilation openings shall be protected against falling dirt.

2.06 Accessories

- A. Where indicated, provide weathershields for outdoor units. When properly installed, weathershields shall provide a NEMA 3R enclosure rating.

Part 3 Execution

3.01 Factory testing

- A. The following standard factory tests shall be performed on the equipment provided under this section. All tests shall be in accordance with the latest version of ANSI and NEMA standards.
 1. Ratio tests at the rated voltage connection and at all tap connections.
 2. Polarity and phase relation tests on the rated voltage connection.
 3. Applied potential tests.
 4. Induced potential test.
 5. No-load and excitation current at rated voltage on the rated voltage connection.

3.02 Installation

- A. The Contractor shall install all equipment per the manufacturer's recommendations and the contract drawings.

3.03 Field adjustments

- A. Adjust taps to deliver appropriate secondary voltage.

3.04 Field testing

- A. Measure primary and secondary voltages for proper tap settings.

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