



Best practices for the installation and inspection of dry-type distribution and power transformers

Introduction

Transformers are often one of the most costly and critical pieces of equipment installed in a power system. In order to achieve the greatest value out of this investment, it is vital that transformers are properly installed, designed, and manufactured.

Installation recommendations found in product literature will always vary from vendor to vendor, but you must always follow local code and the National Electrical Code® (NEC) installation requirements to ensure proper transformer operation.

This paper will explore the most important aspects of dry-type distribution transformers installation and inspection in order to provide general guidelines when evaluating an existing installation or overseeing new construction.

Transformer labeling

When performing an on-site inspection of a facility, it should be a priority to verify that required codes are met for labeling to avoid personnel danger and potential penalties.

Dry-type transformers typically have a nameplate section in the front with exposed terminals behind the front cover. Because this is the main access point, it is usually not necessary to label the other sides.

Manufacturers must also mark each transformer with the name of the manufacturer, rated kVA, primary and secondary voltage, impedance (if 25 kVA or larger), and clearances from ventilating openings.

Look on the transformer for the required clearances, as these are manufacturer's instructions and you must comply with them.

Telltale signs of inadequate electrical products include: missing or poor-quality labels, out-of-date product codes, and absence of, or imitation, third-party testing certification labels from organizations such as Underwriters Laboratories (UL®), the Canadian Standards Association (CSA®), or other bodies that certify the quality and performance of electrical products.



Low-voltage dry-type transformers typical nameplate information

Importance of third-party testing for transformers

The U.S. Department of Energy (DOE) issued a new ruling for efficiency levels for low-voltage dry-type distribution transformers. Technically known as CFR Title 10, Chapter II, Part 431 (in Appendix A of Subpart K 2016), the new efficiency levels are more commonly referred to as the DOE 2016 Efficiency levels.

As of January 1, 2016, these new efficiency levels have gone into effect. Due to the new regulations, manufacturers had to redesign their products to increase the efficiency levels. This is not the first time the industry has experienced a change such as this; in 2007, a similar rule was implemented known as the TP-1 efficiency level.

Minimum efficiency levels have been established for low-voltage dry-type distribution transformers when loaded at 35 percent of their full load capacity, and for oil-based and medium-voltage dry-type transformers at 50 percent loading.

Although the labeling on some products may notate "Certified" testing has been completed, this only applies to values taken during production tests within a manufacturer's facilities and may not accurately represent the claimed minimum efficiency compliance of the transformer.

On the other hand, third-party efficiency verification allows customers to be sure their transformer meets the new DOE 2016 minimum efficiency requirements.

This third-party verification is vital because a DOE 2016 efficient transformer compared with a TP-1 unit will reduce the operation costs of a transformer anywhere from 30 to 35 percent, depending on the kVA, electricity rate and loading profile, among other factors. These savings can range from hundreds to thousands of dollars a year in energy consumption.

In fact, according to the Energy Information Administration (EIA), a sub-agency from the Department of Energy, the savings over a year for the end user would be:

15 kVA...	\$ 43.06
30 kVA...	\$ 70.04
45 kVA...	\$ 100.36
75 kVA...	\$ 142.64
112.5 kVA...	\$ 191.90
150 kVA...	\$ 250.03
225 kVA...	\$ 311.15
300 kVA...	\$ 395.28
500 kVA...	\$ 688.64
750 kVA...	\$ 1,007.56
1000 kVA...	\$ 1,185.39

Note: Savings calculated for a low-voltage dry-type distribution transformer at 35 percent of loading profile.

Pre-installation inspection

When installing a new transformer, one of the most important aspects is the transformer inspection.

New transformers should be inspected upon receipt before removing from cars or trucks to determine if any damage is evident or if there is any indication of rough handling. A claim should be filed with the carrier at once and the manufacturer notified if damage is evident. Insulation resistance and ratio tests may be performed as part of the inspection procedure.

If there is evidence of damage, an internal inspection will be required. In this inspection, note should be made of loose or broken connections, damaged or displaced parts, cracked insulators, dirt or foreign material, and evidence of free water or moisture. Corrective measures should be taken where necessary.

The internal inspection of a ventilated or non-ventilated dry-type transformer can be readily accomplished at a suitably clean and dry location on the site.

Inspection prior to energizing

After a transformer is moved, or if it is stored before installation, the inspection should be repeated before placing the transformer in service.

Additionally, after the transformer is placed in permanent position, shipping braces should be removed, and shipping bolts, if present, should be loosened or removed per manufacturer's recommendations.

For ventilated designs only, if moisture is evident, the unit should be dried out by placing it in an oven or by blowing heated air over it. The temperature should not exceed 110 °C (230 °F) to prevent damage to the transformer's insulation.

Finally, before placing in service, check the operation of fans, motors, relays, and other auxiliary devices. Verify the selection of taps and ratio connections, and double check the tightness and clearance of all electrical connections.



Shipping damaged transformer

3rd party verified



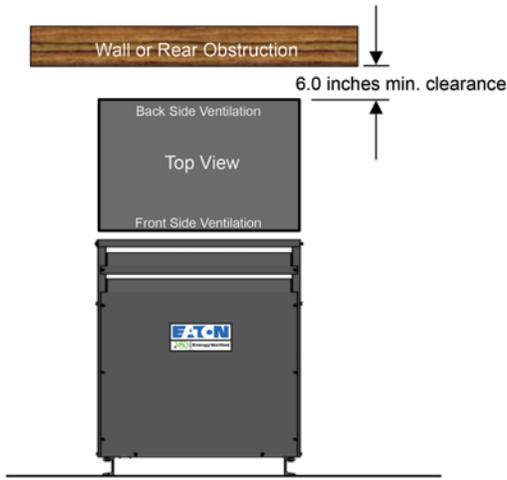
**Meets the most stringent government regulations ever—
35% improvement over TP-1. Look for the UL verification seal**

UL verification mark example

Installation basics for dry-type distribution transformers

Clearance

Accessibility for maintenance should be considered when locating dry-type transformers. Transformers should be located so that there are sufficient clearances from walls (per manufacturer guidelines) and other obstructions, and sufficient spacing between transformers to permit the unrestricted opening of hinged or removable doors, covers, and panels for the purpose of inspection, maintenance, and testing. Adequate space should also be provided to accommodate such barriers and guards as necessary to protect personnel performing these functions.

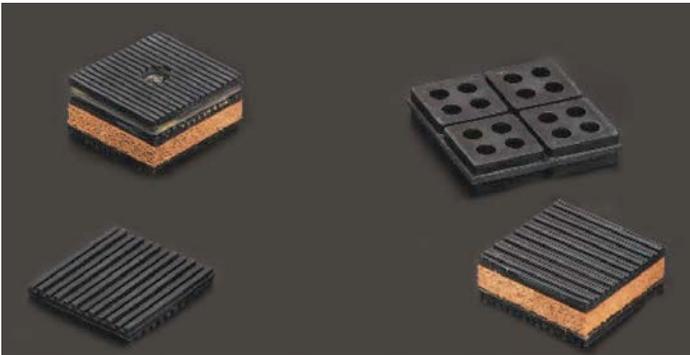


Typical installation transformer-to-wall clearance for low-voltage dry-type transformers

Sound dampening

To minimize sound transmission to surrounding structures, it is recommended that the transformer be installed away from corners, walls, or ceilings. For installations that must be near a corner, sound absorbing materials can be used on the walls and ceiling.

The use of flexible conduit to make the connections to the transformers is also recommended to reduce vibration and sound transmission.



Vibration isolation options

Future removal

When located inside buildings, transformer rooms, or enclosures, means should be provided to permit the removal and replacement of a unit in the event of a failure. A route should be available that provides entrances, doorways, and passages with sufficient clearances to permit removal of the transformer. Electrical and mechanical connections of the transformer to other electrical equipment should be of a type that will permit the removal of the transformer without removal or major disassembly of the other equipment.

For dry-type transformers located in high-rise buildings, there is the particular challenge of accessibility. In many instances, particular attention to the design of the transformer may permit the use of the building elevator system for removing and replacing damaged units. Partial disassemble of enclosure and/or core-coils may further increase the size of a unit that can be moved by the building elevators. When transformers are too large to be removed by an elevator, a means of removing these transformers should be provided. In many cases, a mobile crane can be a satisfactory alternate. When mobile cranes are not available or the height of the building is beyond their capability, booms or cranes mounted on the roof of the building either permanently or temporarily should be considered.

Personnel and public safety

Dry-type transformers should be specified to have all necessary protection and safeguards so that they do not represent a hazard to the general public, workmen in the area, or personnel working on the transformers.

To the extent that it is practical, rooms and spaces in which dry-type transformers are installed should be so arranged with fences, screens, partitions or walls, or other means to prevent entrance by unauthorized persons. Warning signs should be prominently displayed at all entrances. UL 5085, UL 1561, and IEEE® Std C57.12.01 describes electrical, mechanical, and safety requirements and conformance tests that should be considered to help ensure safe operation of the transformer.

Room requirements

Dry-type transformers located indoors should comply with the application requirements of the NEC.

The room in which dry-type transformers are located should be sized to permit locating transformers with sufficient spacing between units and sufficient clearances to walls and other obstructions to permit the free circulation of air around each unit. Sufficient space should also be provided to permit routine inspection and maintenance.

Adequate ventilation is essential for the proper cooling of transformers. Clean, dry air is desirable. Filtered air at or above atmospheric pressure may reduce maintenance if dust or other contaminants present a particular problem. When transformers are located in rooms or other restricted spaces, sufficient ventilation should be provided to hold the air temperature within established limits when measured near the transformer inlets. This will usually require approximately 3 m³/min of air per kilowatt of transformer loss. The area of ventilating opening required depends upon the height of the room, the location of openings, and the maximum loads to be carried by the transformer.

Further, room ventilation should not impede normal circulation of air through the transformer. When possible, the air inlet to the room should be near the floor with the outlet in the opposite upper end of the room. The exhausting air should not exceed 15 °C above the inlet air temperature. When necessary, forced air exhaust should be used to maintain this maximum differential. For self-cooled transformers, the required effective area should be at least 19 cm² of inlet and outlet area per kilovolt-ampere of transformer capacity in service except the required effective area should be at least 930 cm² for any capacity under 50 kVA, after deduction of the area occupied by screens, gratings or louvers.

Outdoor applications

Dry-type transformers may be used in outdoor locations with suitable protective measures such as weather-resistant enclosures, vehicular traffic guards, and adequate drainage. In addition, accessories such as gauges, control, and terminal chambers must be suitably protected. When located in areas accessible to the general public, the transformer enclosure must be tamper-resistant and must otherwise meet the requirements of the NEC.

The weather-resistant enclosure may be an integral part of the transformer or separate from the transformer. The enclosure should be constructed to limit the entry of water (other than flood water) so as not to impair the operation of the transformer. All ventilating openings should be specified to have baffles, grills, or barriers that effectively prevent the entry of rain, sleet, or snow. Non-ventilated dry-type transformers should be provided with a weather-resistant enclosure when used in outdoor applications.

Facility management teams should also consider ambient temperature and altitude. Under normal conditions, standard rating dry-type distribution transformers can be installed at an altitude of less than 1000 m (3300 ft), with an ambient temperature that does not exceed 30 °C as a daily average or 40 °C at any time, and which does not fall below -20 °C. If the ambient temperature exceeds standard conditions or if the unit will be installed at a high elevation, you should work with the manufacturer to specify a transformer that is rated higher than what the load requires to compensate for local conditions. You can refer to NEMA® ST 20 for detailed de-rating guidelines.



NEMA Type 3R enclosure (with weathershields) low-voltage dry-type transformer for outdoor applications

Inspection basics

Overcurrent protection

The first item you need to look at is NEC 450.3 Overcurrent Protection. In 450.3(B) Transformers 600 Volts, Nominal, or Less, you are directed to use a table to provide overcurrent protection for typical transformers, Table 450.3(B).

It is important to note that the table is based on current values, with the first column at 9 A or more; this is where you'll find values for the transformers generally seen installed in building construction. The table has two rows; the first row is used when only primary overcurrent protection is provided.

As you can see in the table, it is limited to 125% with a note stating that you can round up to the next standard size as per NEC 240.6. The second row is for instances where you can find the level of protection needed on both the primary and secondary side of the transformer; under these conditions you are allowed to move up to 250% on the primary side and 125% on the secondary side. In other words, you should provide double protection so that the primary is basically protecting the transformer itself, and the secondary protection is providing the required protection needed for the conductors being fed from the transformer.

Table 450.3(B) also covers transformers at lower current values. Smaller current transformers, such as 2 A or less, are usually found in control cabinets.

One of the first things you'll need to check for when doing inspections is how the transformer is being protected and whether it is done correctly per the table. Often you'll find installations where the primary is protected at 250% and there is no secondary protection. Generally, conservative design professionals call for both primary and secondary protection.

NEC Table 450.3(B) Maximum Rating or Setting of Overcurrent Protection for Transformers 1000 Volts and Less (as a percentage of transformer-rated current)

Protection method	Primary protection		Secondary protection ¹	
	Currents of 9 A or more	Currents less than 9 A	Currents less than 2 A	Currents of 9 A or more
Primary only protection	125% ²	167%	300%	Not required
Primary and secondary protection	250% ³	250% ³	250% ³	125% ²

- ¹ Where secondary overcurrent protection is required, the secondary overcurrent device shall be permitted to consist of not more than six circuit breakers or six sets of fuses grouped in one location. Where multiple overcurrent devices are utilized, the total of all the device ratings shall not exceed the allowed value of a single overcurrent device.
- ² Where 125 percent of this current does not correspond to a standard rating of a fuse or non-adjustable circuit breaker, a higher rating that does not exceed the next higher standard rating shall be permitted.
- ³ A transformer equipped with coordinated thermal overload protection by the manufacturer and arranged to interrupt the primary current shall be permitted to have primary overcurrent protection rated or set at a current value that is not more than six times the rated current of the transformer for transformers having not more than 6 percent impedance and not more than four times the rated current of the transformer for transformers having more than 6 percent but not more than 10 percent impedance.

Inrush current

Inrush current is an important consideration when selecting an overcurrent protection device (OCPD) to protect dry-type distribution transformers, because if sized incorrectly, the OCPD may operate during system startup and prevent the transformer from energizing.

In the past, many design engineers took advantage of NEC Article 450 Table 450.3(B) and sized primary OCPDs for low-voltage distribution dry-type transformers at no more than 125% of the transformers' full load primary amperes (FLA). With the primary OCPD sized at 125%, the transformer is fed with the lowest cost cable and conduit, providing adequate overload and short-circuit protection for the wire and for the transformer primary and secondary. In addition, the protection is well below the damage curve of the transformer (NEMA ST 20 requires the transformer to withstand 20–25 times FLA for 2 seconds for standard dry-type transformers). The other factor allowing this selection to work is that the transformer inrush currents were typically 4–10 times its primary FLA rating.

However, with the advent of the 2007 (2010 for oil and medium voltage) DOE legislation, the desire to use higher efficiency transformers and the specialty transformers, the industry started to experience some nuisance tripping of the primary OCPD when sized at 125%.

And now with the possibility of even higher inrush currents as a result of DOE 2016, this topic takes on additional importance. Today it is not uncommon for the theoretical maximum transformer inrush currents to be as high as 20–30 times the primary FLA of the transformers.

When this possibility for higher inrush currents is compounded with the many variations in construction methods and materials between manufacturers, and even between transformer types/ratings from the same manufacturer, it becomes extremely important for engineers to verify inrush current values.

To help customers with this new challenge, some manufacturers design and test standard (or most common) DOE 2016 transformers to allow the primary OCPD to be sized at 125%. However, this may not be the case with all manufacturers.

It is also important to note that manufacturer published inrush values are most often descriptive of transformers that are energized from the primary winding, which is the outer windings of a transformer. If the transformer is reverse fed and energized from the secondary winding, which is the inner windings, you can expect the inrush values to be dramatically greater. To address this issue, engineers should always be cautious of back feeding applications and select the largest OCPD allowed by code.

Ventilation

Don't allow transformer-ventilating openings to be blocked by walls or other obstructions [NEC 450.9]; the required clearances shall be marked on the transformer. Not all obstructions may be apparent or present at the time of installation. Anticipate what other equipment will go in that location, by consulting the property owner and the construction drawings.

Installation of one transformer above another should be avoided due to the heat transfer from the bottom unit to the top transformer through the hot air coming from the exhaust ventilations. The unit at the bottom will increase the ambient temperature of the top unit overheating it, resulting in a reduction of its expected life.



Example of a bad installation

Accessibility

For transformers rated 600 V or less, install them so they are readily accessible to qualified personnel for inspection and maintenance [NEC 450.13]. Two exceptions exist:

- Open installations. You can locate dry-type transformers in the open on walls, columns, or structures (NEC Figure 450.6).
- Suspended ceilings. You can install dry-type transformers (rated not more than 50 kVA) above suspended ceilings or other hollow spaces of buildings not permanently closed in by the structure (NEC Figure 450.7).

Means of disconnect

In NEC 450.14 Disconnecting Means, you'll find the requirement for a disconnecting means to isolate the transformer from power. The disconnecting means can either be in sight of the unit or in a remote location, as long as the disconnecting means meets the required locking feature and there is a label on the transformer indicating where the disconnect is located.



Disconnecting means to isolate the transformer from power

Fire protection

The most common transformers you'll find during inspections of building construction are dry-type, and NEC 450.21 provides further information related to these depending on the size and voltage. It is important to become familiar with the exceptions from section 450.21 because if properly applied, these exceptions allow for a much flexible and safe installation.

For example:

- If the transformer is 112.5 kVA or smaller, the code requires a 12-inch separation from a combustible, unless separated by a fire-resistant or heat-insulated barrier

Exception: This rule shall not apply to transformers rated for 1000 volts or less that are completely enclosed, except for ventilating openings.

- When the transformer is over 112.5 kVA, the code requires that the transformer be installed in a room of fire-resistant construction, usually with a minimum of 1 hour rating

Exception No. 1: Transformers with Class 155 or higher insulation systems and separated from combustible material by a fire-resistant, heat-insulating barrier or by not less than 1.83 m (6 ft) horizontally and 3.7 m (12 ft) vertically.

Exception No. 2: Transformers with Class 155 or higher insulation systems completely enclosed, except for ventilating openings.

The transformer enclosure provides a valuable protection against fire hazard, although it is important to maintain the ventilating openings free of obstructions and combustible materials at all times.

This is a building code requirement. If you're unsure of a room rating, you can check with the local building inspector for the site.

Conductor size

When looking at transformers, there are code requirements related to the size and length of the secondary conductors. These requirements are located in NEC 240.21(C), where you'll find the length of these conductors related to the application. The language provides us with the proper sizing rules, requirements for physical protection, and indicates that they must terminate into a single circuit breaker or set of fuses.

An installation item to be aware of when inspecting transformers is that the manufacturer will usually place a label inside with a line indicating that all conductors must be kept below the line. Many times the installers don't see this note or they ignore it. When applied, this note becomes part of the installation requirements for that unit and must be followed.

Lighting taps

Lighting taps, also known as center taps, can be found on delta-delta connected transformers. Their principal function is to serve loads no greater than the 5% of the rated output power. Ignoring this rule will result in unbalanced load and circulating currents that compromise the transformer.

One of the most common voltage configurations for lighting taps is 480D-240D 120 lighting tap, which can be confused with a 480D-208Y/120 delta-wye that can be fully loaded with three-phase loads at 120 V. Lighting taps are, because of their nature, very limited in the amount of power they can deliver and should never be considered as a substitution for a delta-wye transformer.

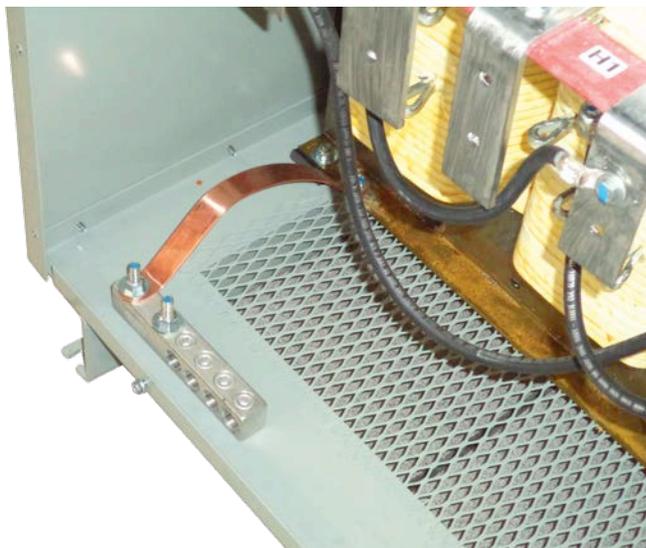
Aluminum vs. copper windings

There is a common misconception that a low-voltage dry-type transformer with copper windings is in some way more efficient, more reliable, or has higher short-circuit strength when compared to a transformer with aluminum windings.

Technological improvements in the aluminum alloy used in transformer windings have made aluminum-wound transformers the preferred choice for today's applications. Aluminum-wound coils are built to meet the same thermal, dielectric and mechanical performance requirements as copper-wound coils.

Grounding

For grounding dry-type transformer enclosures, a terminal bar for all grounding and bonding conductor connections should be secured inside the transformer enclosure in accordance with NEC 450.10(A)—and not installed on or over any vented portion of the enclosure.



Eaton's low-voltage dry-type transformer bonding/grounding bar

Torque

Proper torquing while installing low-voltage dry-type transformers plays an important role in order to reduce fire hazard as a result of loose connections. Transformer manufacturers recommend applying specific torque values to electrical connections (mechanical lugs on terminal board, tap changing connections, current carrying bus bars within customers wiring space, and others). Always refer to the manufacturers' installation manual for electrical torque recommendations.

Torque values on transformer mechanical bolted joints should be considered at installations with special mounting requirements such as low sound areas and seismic zones. For more information, visit www.eaton.com/seismic.

Electrical connection torque is a very important part of the installation, as poorly torqued connections can lead to hot spots that will affect the efficiency of the transformer, resulting in higher cost of operation and shorter life span of the overall installation.

There are a great variety of connectors in the industry, although for dry-type distribution transformers, most manufacturers recommend mechanical lugs. Before a mechanical lug is used, there are several aspects to keep in mind:

1. The connector shall be capable of terminating the conductor; most mechanical lugs cover a range of conductor sizes. Use the NEC to select the proper conductor ampere rating.
2. Aluminum connectors should be dual-rated for Cu and Al conductors. The marking on the conductor indicates the conductor material and temperature ratings, for example:
 - AL9 Aluminum
 - AL9CU or CU9AL Aluminum/Copper
 - AL7 Aluminum
 - AL7CU or CU7AL Aluminum/Copper



Mechanical compression lug

3. The temperature rating of the connector must be in accordance to the conductor and transformer marking. By standard, the transformer manufacturer should mark the temperature rating of the conductor.
4. The marking on mechanical connectors is normally suitable for only one conductor, unless the connector manufacturer specifically allows for more than one conductor.
5. For compliance with safety standards, wire connectors like the ones used for transformers should bear the UL and CSA mark as proof of compliance.

On a mechanical connector, there are two torques to be considered:

A. Internal socket connections

The internal socket torque values are defined by the connector manufacturer. For ILSCO connectors, the torque values are:

Internal socket size across flats (inches)	Tightening torque (in-lb)	Internal socket size across flats (inches)	Tightening torque (in-lb)
1/8	45	5/16	275
5/32	100	3/8	375
3/16	120	1/2	500
7/32	150	9/16	600
1/4	200	—	—

B. Bus bar bolted connections

ANSI/NEMA CC 1-2009 Table 4-4 shows the nominal torque values for bus bars bolted connectors.

**Table 4-4
Nominal Torque Values**

Diameter of Bolts			Torque		
In	mm	Material	N-m	lb-ft	lb-in
1/4	(6.3)	SB	9	7	80
5/16	(7.9)	SB	20	15	180
3/8	(9.5)	SB	27	20	240
1/2	(12.7)	SB	54	40	480
5/8	(15.9)	SB	75	55	660
3/4	(19.1)	SB	118	87	1050
3/8	(9.5)	LA	19	14	168
1/2	(12.7)	LA	34	25	300
5/8	(15.9)	LA	54	40	480
3/4	(19.1)	LA	73	54	650

NOTES:
LA= Lubricated - Aluminum
SB = Silicon bronze or Steel

For optimum conductivity, it is necessary to properly select the bolt, nut, and washer combination to be used with the proper combination of conductor materials. For hard drawbars, such as the transformer terminals, large flat washers in combination with split lock washers are recommended. Environmental factors should also be considered when selecting the hardware. In addition to the transformer terminals, another electrical connection may be required depending on the input voltage. The coil taps for a dry-type distribution transformer are in most cases made from the coil conductor. For such connections, the torque to be applied greatly depends on the individual characteristics of the transformer, although a torque value of 95 in-lb for copper windings and 70 in-lb for aluminum can be used for most configurations.

Backfeeding

According to NEC 450.12(B), a transformer shall be permitted to be supplied at the marked secondary voltage, provided that the installation is in accordance with the manufacturer's instructions.

Transformers labeled as "bi-directional" are suitable for such applications (back-feeding). Normally, transformers are designed to have the incoming cables connected to the primary terminals, but transformers marked as bi-directional are suited to have the incoming cables connected to the secondary terminals.

If the secondary is a delta connection with a center tap (e.g., lighting tap or convenience tap), the center tap (normally X4) cannot be connected.

A transformer can be reverse-fed, although there are limitations that must be considered when such application is being considered:

- **Grounding**

When the transformer is a delta/wye configuration, the neutral of the wye should not be connected to the ground nor be bounded to the transformer's enclosure. The output delta B phase can be grounded if the system allows it; NEC 450 must be followed to determine if such grounding configuration is possible.

- **Taps**

By design, the taps are meant to adjust the transformer input voltage to the actual voltage applied at the transformer terminals; therefore, when reverse-feeding, the taps will be reversed.

- **Over-excitation**

The secondary side of the transformer lacks of taps; therefore, the input voltage cannot be adjusted, which can result in an over-excitation of the transformer core if the input voltage is higher than the rated secondary voltage.

- **IR-drop compensated transformer**

Some transformers have IR-compensation, which is a provision in the transformer by which the voltage drop (due to transformer load current and internal winding resistance) is partially or completely neutralized; normally transformers 3 kVA and below are compensated for the IR-drop.

- **Inrush current**

When a transformer is first energized, an inrush current is demanded from the grid to which the transformer is supplied. This higher than normal "inrush" current can be 20–30 times the primary FLA of the transformers, and it may flow for several cycles. When the transformer is being reverse fed, the inrush will be much higher and may cause nuisance tripping of overcurrent protection devices. The usage of time-delay breakers and fuses may be used.

Summary

As electrical professionals, it is your duty to perform thorough inspection and verification when evaluating transformers. The results can be dramatic with consequences ranging from extended power outages, costly downtime and code infractions with associated fees to unexpected energy cost, damage to equipment and endangering the safety of personnel.

This white paper is intended to serve as a guide for the most common and important items to look for, but the NEC should always be referenced as standards, technology, and power system demands continue to evolve.

Transformers play a critical role in ensuring proper power distribution system operation, and knowing what part of NEC applies to each aspect of installation is equally important.

To learn more, contact your local representative or visit
Eaton.com/transformers

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