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## DRIVE ISOLATION TRANSFORMERS— SOLUTIONS TO POWER QUALITY

### Introduction

The increased use of ac and dc motor drives in industrial plants has elevated the power quality application considerations associated with power distribution systems. These considerations have sparked great controversy about the use of drives in industrial applications and have raised questions about their effects on an electrical system. Valuable guide standards, such as IEEE 519-1992, have been created to help consulting and facility engineers evaluate harmonic current and voltage distortion in their facilities. Some problems can only be solved by re-routing major electrical systems or use of harmonic filter equipment. Improper grounding techniques or improper maintenance of equipment and connections cause additional electrical system problems. The aim of this product data bulletin is to provide information and guidelines on the use of drive isolation transformers for solutions to power quality.

### Motor Drives

Motor drives of all types share a common characteristic; they rectify incoming power to form a dc level, either by a static diode bridge rectifier, or by silicone controlled rectifier (SCR) phase control. For a dc motor drive, the dc power is connected directly to a dc motor. For an adjustable frequency motor drive, the dc power is used to power an inverter, which supplies adjustable frequency and voltage to ac motors.

In both cases, the “front-end” rectification causes the current waveform to be nonsinusoidal, or “nonlinear” in nature. In the special case of three phase motor drives using SCR 6-pulse rectifiers, there are short intervals of time when more than one SCR is on. This causes a transient “short circuit,” or peak in current, to flow six times per line power cycle.

Distorted current flow causes non-linear voltage to drop across the system impedance, resulting in distorted voltage. This distortion can have serious effects on other equipment connected on the same service. Many types of sensitive electronic equipment, such as UPSs, computers, process controllers, data communication systems, and even electronic ballasts can be exposed to voltage distortion that exceeds the design “window” for their power requirements. In addition to harmonic voltage distortion, the high current peaks of dc motor drives can cause “notching” in the voltage, which some equipment is unable to tolerate, see figure 1, page 2. In systems with large amounts of power factor correcting capacitors, high voltage distortion can cause resonance at system harmonic frequencies. This results in high-series or parallel-resonant currents, which can be very damaging to the electrical system.

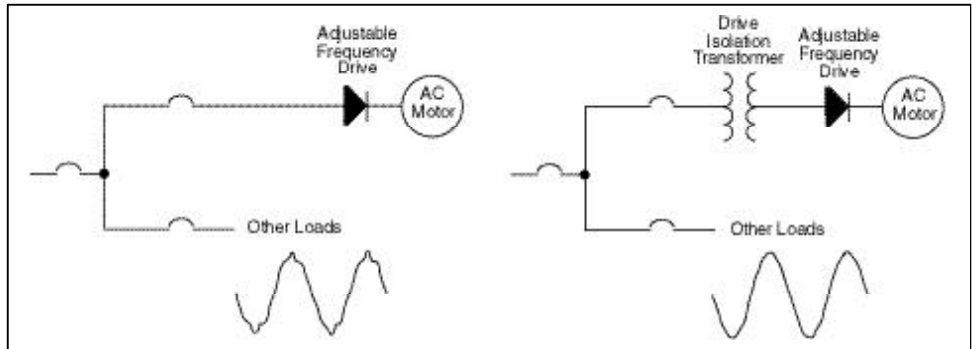
### Drive Isolation Transformers

To reduce the effects of motor drives on other loads in the electrical system, one common technique is to add reactance in the incoming power to the motor drives. The added reactance ahead of a motor drive can actually reduce the amount of distortion present in the input current to the motor drive.

Drive Isolation Transformers (cont.)

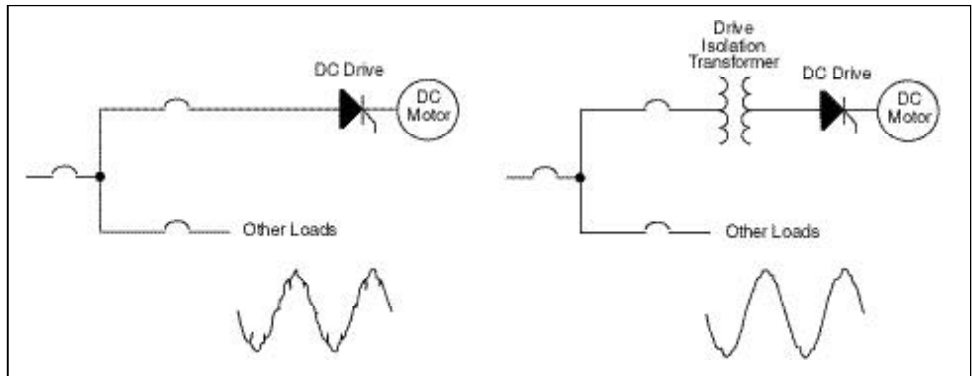
Drive isolation transformers provide reactive control of current harmonics for both ac and dc motor drives, either static bridge or SCR switch input type. Reducing current harmonics has two benefits:

1. It decreases line current waveform distortion, which improves the power factor of the motor drive load.
2. It reduces voltage waveform distortion effects in the feeders ahead of the transformer. Reducing voltage distortion can prevent motor drives from affecting sensitive loads, even other motor drives, elsewhere on the service.



**Figure 1: Drive isolation transformers reduce harmonic voltage distortion effects of adjustable frequency and dc drives.**

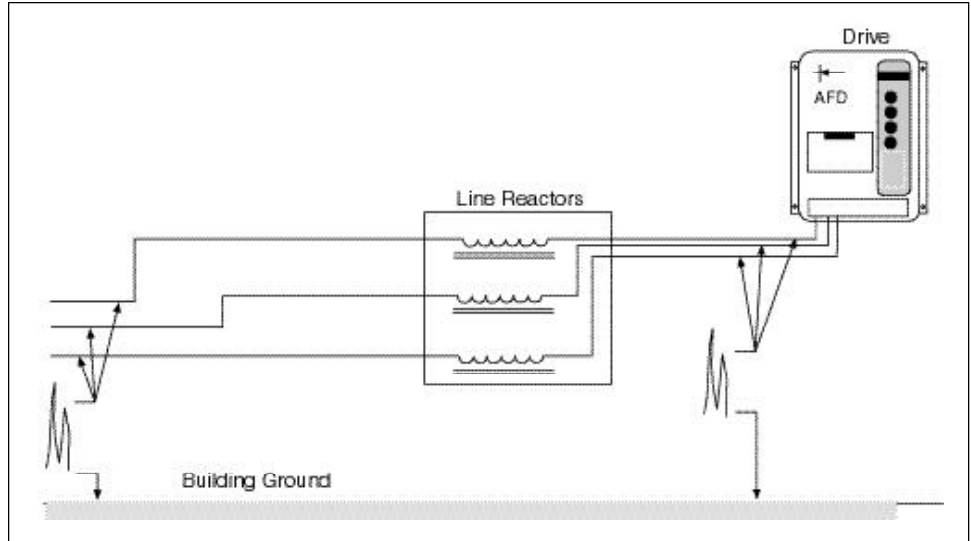
Transformer reactance can also reduce line notching effects on the system voltage, effects that are caused by SCR switching overlap. The current spikes from dc drives impose a notching effect in the supply voltage; the severity of the effect depends on the voltage source impedance. The addition of a drive isolation transformer can reduce the line notching effect.



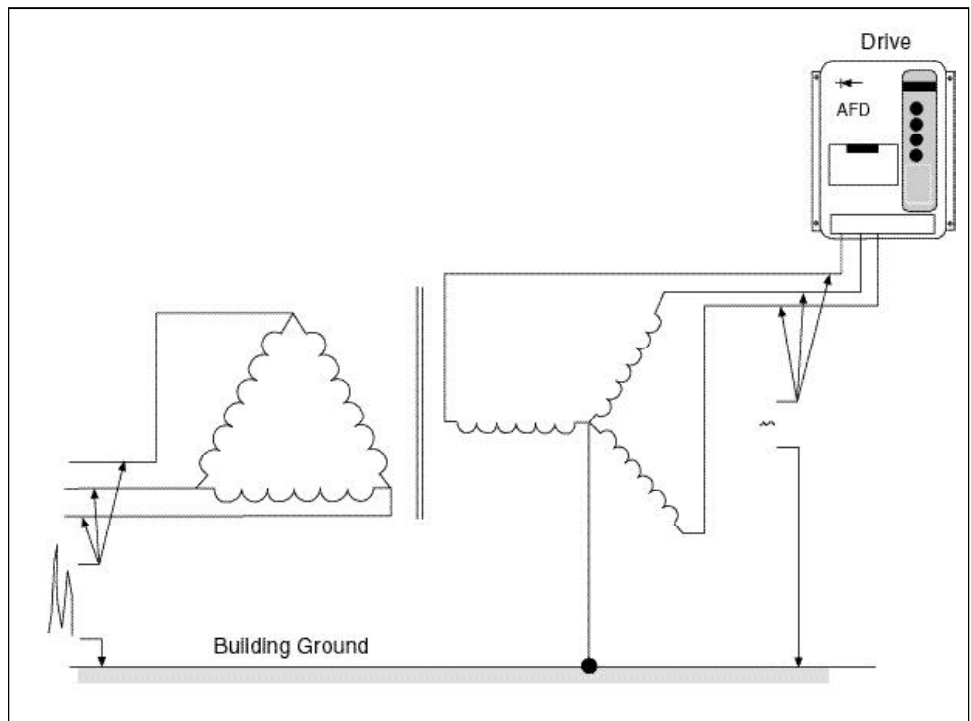
**Figure 2: Use of drive isolation transformers reduce source voltage notching.**

Unlike simple line reactors, the secondary of a drive isolation transformer represents a separately derived power supply that is electrically isolated from the primary source. If the secondary is wye connected, it can be grounded. Grounding prevents the transfer of common-mode noise and transients, both from the primary source to the motor drive, and from the drive to the primary system. Compare figures 3 and 4 to see the difference in the use of line reactors and drive isolation transformers.

Drive Isolation Transformers



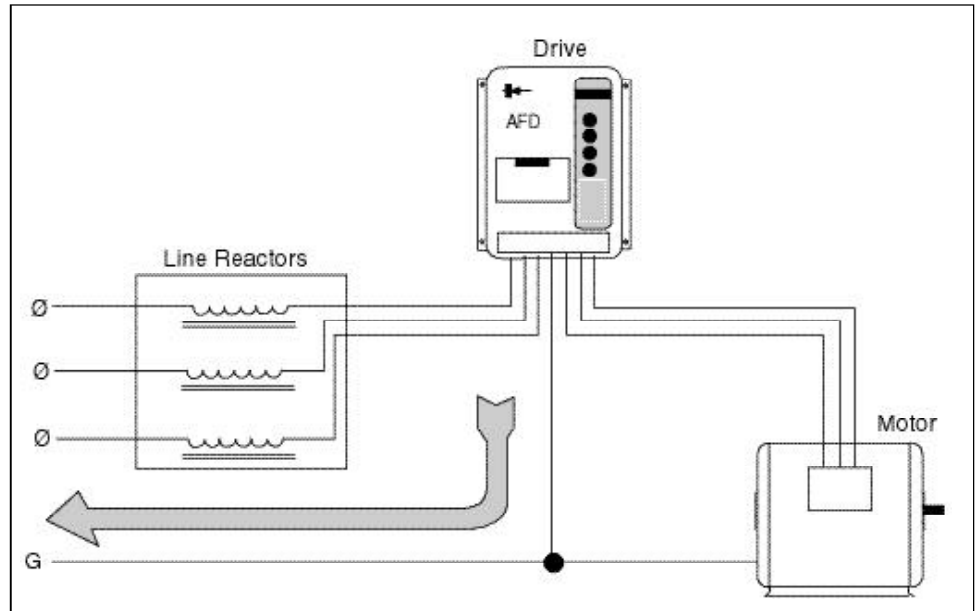
**Figure 3:** Line reactors do not provide protection from common-mode energy, which is generated from the line or from the motor drive.



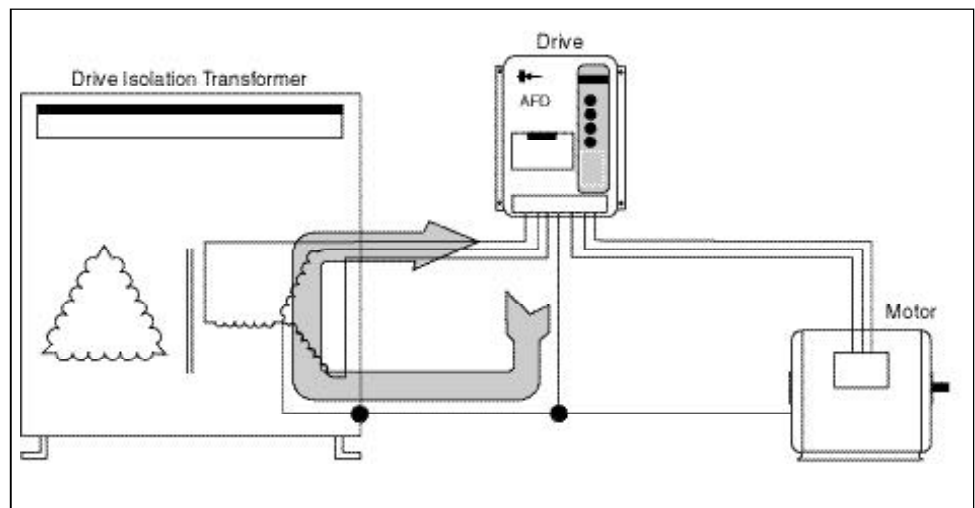
**Figure 4:** The isolated secondary of a drive isolation transformer allows grounding, which eliminates common-mode transient energy.

Motor drives can introduce large induced ground currents. This is due to rapid current changes caused by diodes, SCRs, or pulse width modulated (PWM) outputs that couple currents capacitively through ground back to the source. High-frequency induced ground currents are a major cause of data disruption in digital communication and nuisance tripping of ground fault systems. Introducing a grounded, drive isolation transformer localizes the ground current effect and prevents it from extending upstream from the transformer. Again, line reactors alone do not provide this feature.

Drive Isolation  
Transformers (cont.)



**Figure 5:** Line reactors allow induced ground current and noise from motor drives to return into the primary source, affecting other loads on the service.



**Figure 6:** Induced ground current and noise from drives returns through the grounded secondary of an isolated transformer, and is prevented from traveling into the primary source.

Loads incorporating static diode rectification present distorted current waveforms to the transformer windings. This distortion causes additional heating in the coils. Three-phase SCR controlled loads introduce similar harmonic heating effects and present high-level current transients during commutation overlaps. Drive isolation transformers should be designed to accommodate the additional heating effects of the distorted current of both ac and dc motor drives. In addition, drive isolation transformers need to withstand the mechanical forces in their coils that result from SCR overlap current spikes, which are typical for dc drives. Also, drive isolation designers must consider the thermal and mechanical stresses caused by the highly cyclic load demands of both dc and adjustable frequency motor drive process applications.

Drive Isolation  
Transformers

Many loads have characteristics similar to ac and dc motor drives. This is because the load inputs are either designed with three-phase static diodes or three-phase, 6-pulse, SCR bridge rectifier circuits. Drive isolation transformers can also control the effect of these loads on the primary power system. General equipment applications for drive isolation transformers include:

- SCR controlled heating or furnaces
- three-phase rectifier input dc power supplies
- three-phase switched-mode power supplies

## Questions

**Q.** *What problems can be solved by using line reactors or drive isolation transformers?*

**A.** Using line reactors and drive isolation transformers can reduce distortion of the motor drive current. Current distortion causes voltage distortion, which can effect other loads. If a motor drive is causing sensitive equipment to malfunction, lighting to flicker, or other drives to act erratically, then reactive isolation techniques *may* be effective. However, complete understanding of the problems, their causes, and the effect of adding reactance to the system is essential before implementing any power solution.

**Q.** *Can standard, general purpose transformers be used as drive isolation transformers?*

**A.** General purpose transformers are not fully rated for drive applications because they cannot supply the required distorted current at full load without exceeding their design temperature rise. In addition, many standard transformers have shortened life expectancy due to mechanical stress when these transformers supply dc drive current transients. Another contributor to shortened life expectancy is the generally severe cyclic nature of drive process control applications.

**Q.** *Since UL has established a K-Factor rating system for transformers that supply non-linear loads, do drive isolation transformers need K-Factor ratings?*

**A.** The UL K-Factor test evaluates temperature rise only. That is fine for relatively passive applications such as computers and other office equipment loads. Drive isolation transformers are subjected to much more mechanical stress and thermal and mechanical cycling effects than K-rated transformers. In addition, a motor drive's K-Factor depends on the reactance of the line to which it is connected. In other words, the transformer and the system, not the motor drive, determines the K-Factor. Therefore, choosing a universally appropriate K-Factor rating for a drive isolation transformer is impossible. Most importantly, most K-Factor rated transformers have insufficient reactance for proper drive harmonic control.

**Q.** *When voltage change is not necessary, what is the benefit of drive isolation transformers over line reactors?*

**A.** Drive isolation transformers and line reactors both provide reactive control of distorted current harmonics and line notching. However, that is the extent of their similarity. Drive isolation transformers provide additional benefits because their wye-connected secondary can be grounded. This protects the motor drive system from common-mode transients that originate from the primary source. These transformers also protect the primary source from common-mode energies that originate from the motor drive system. In addition, separately grounding the transformer secondary prevents ground currents from transferring back through the primary ground system (a well known undesirable characteristic of motor drives).

Questions (cont.)

**Q.** *Why are drive isolation transformer ratings for kVA and voltage so different from general purpose transformers?*

**A.** The industry has standardized ratings on drive isolation transformers to match typical motor ratings. Motors are typically rated at 575V, 460V, or 230V, as opposed to the standard distribution voltages of 600V, 480V, or 240V. Standard motor horsepower ratings are converted to transformer sizes, which are measured in kVA. In this conversion, an additional factor is included to cover the energy losses in the motor drive itself. The table below shows typical conversions from motor drive horsepower to kVA.

Drive HP	Transformer kVA	Drive HP	Transformer kVA	Drive HP	Transformer kVA
5	7.5	30	40	125	145
7.5	11	40	51	150	175
10	15	50	63	200	220
15	20	60	75	250	275
20	27	75	93	300	330
25	34	100	118	400	440
				500	550

**Q.** *What standards encompass drive isolation transformers?*

**A.** No standards differentiate transformers rated for motor drives from general purpose transformers. For this reason, it is important to specify the features that differentiate them. Many vendors are merely relabeling their standard general purpose line for use as drive isolation transformers, so ***distrust the lowest bidders!*** To ensure that the transformer supplied is truly rated for motor drives, make sure the vendor is able to prove it through tests that follow UL Standards 1561 or 1562. The tests should prove that the drive current distortion effects do not cause coil overheating. In addition, IEEE Standard 597 requires that drives be capable of supplying 150% of rated current for one minute out of each hour. Transformers rated for motor drives must be capable of those same overload cycles. Since one of the major benefits of using drive isolation transformers is to provide sufficient line reactance to reduce the effects on other parts of the electrical system, minimum reactance specifications are important, see **Specification Highlights**. Finally, particularly in the case of dc drives, the vendor should have extensive field experience in providing coil design with adequate mechanical strength to ensure long life expectancy in high surge current applications.

**Q.** *I've used standard, general purpose transformers for drive applications for years with no problems. Why should I specify drive isolation type?*

**A.** Most transformers are not used at their full capacity. For this reason, many less-than-ideal transformer designs survive in the field, despite drawbacks in quality and design suitability. In process control applications, for example, many drive systems are designed to handle peak loading, while the average loading over 24 hours is quite low. Some applications have much more impact on drives and transformers. Paper mill, spooling, and steel mill processing are a few applications where transformers have notably higher failure rates. Second, the reactance of general purpose control transformers is not guaranteed to be sufficient for reducing the effects of the drive on upstream systems. The purchaser or specifier has the responsibility to provide product designed and warranted for the application.

## Questions

**Q.** *Do drive isolation transformers or line reactors always reduce the effect of motor drive current distortion on service voltage?*

**A.** Not always. For example, if the power required by a motor drive represents a substantial percentage of the service capacity, introducing additional reactance will have much less effect than with larger service kVA/drive horsepower ratios. This is because the reactive *change* that the motor drive “sees” in upstream reactance dictates the changes in current distortion that the drive injects into the system. A primary system that is too small for the motor drive already introduces a lot of reactance to the motor drive. Adding additional line reactance may have little effect in these cases.

**Q.** *Are electrostatic shields effective in drive isolation transformers?*

**A.** Electrostatic shields can prevent common-mode noise from transferring from the transformer’s primary to the secondary only if the secondary is ungrounded. Some tests have shown that the typical noise and transients in industrial systems is actually transferred better through shielded transformers than those without shields. If the drive transformer has an ungrounded secondary, or if a high-resistance ground system is used, an electrostatic shield may be beneficial. However, if the drive isolation transformer’s secondary is grounded, primary source common-mode noise cannot be induced between the secondary neutral and ground. Under these conditions, an electrostatic shield serves no useful purpose.

**Q.** *Is grounding of the secondary of a drive isolation transformer recommended?*

**A.** In general, grounding the secondary provides three valuable benefits:

- It provides superior transient and impulse immunity to the load side of the transformer.
- It reduces common-mode noise coupling from primary to secondary.
- It prevents induced ground currents from transferring upstream into the primary system.

However, a few motor drive designs do not function properly if the secondary neutral is grounded. In this case, the motor drive manufacturer’s recommendations would have to be followed, therefore, losing the benefits of a grounded secondary, and ignoring the consistent recommendation of IEEE that operating equipment on grounded systems is preferred.

## Specification Highlights

Recommended requirements for drive isolation transformers:

- Evaluated according to UL Standard 1561 or 1562 for effects of harmonic heating
- Designed for typical harmonics per IEEE 519-1992
- Meets 4% minimum reactance for 150°C temperature rise designs
- Conforms to IEEE-597 Class B overload, which requires 150% of load for one minute per hour
- Designed for the mechanical stress of dc drive current spikes
- Designed for the thermal and mechanical stress of highly cyclic process control applications

Functional Comparison of  
Line Reactors and Drive  
Isolation Transformers

Function	Drive Controller Lineside Converter			
	6-Pulse Converter Operating with Capacitive Load (most adjustable frequency drives)		6-Pulse Converter Operating with Inductive Load (most dc drives)	
	Reactors	Drive Transformer	Reactors	Drive Transformer
Match system voltage to drive rating	Not Possible	Best	Not Possible	Best
Meet local or plant codes requiring isolation	Not Possible	Best	Not Possible	Best
Capable of correcting line voltage unbalance	Not Possible	Best	Not Possible	Best
Provides continuity of service for nuisance grounding	Not Possible	Best	Not Possible	Best
Reduces drive induced currents in supply feeder ground	Not Possible	Best	Not Possible	Best
Reduces common-mode impulses and electrical noise	Poor	Best	Poor	Best
Reduces line current harmonic injection into primary source	Good	Good	Poor	Poor
Reduces source voltage notching effects	N/A	N/A	Good	Good
Reduces available feeder short circuit capability	Best	Good	Best	Good
Meet specified line impedance requirements	Best	Good	Best	Good
Reduces differential-mode impulses	Good	Good	Good	Good

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