# Transformer Electrostatic Shields

**Retain for future use.**

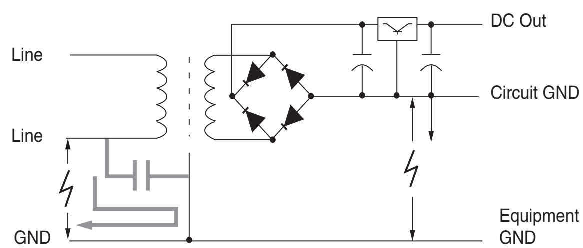
## Overview: Shields and Grounding

Transformers are often specified with electrostatic shields on the assumption that the shields help protect load equipment on the secondary from primary system impulses and surges. The practice of using inter-winding shields in transformers for electrical disturbance protection originated in the electronics industry.

Before the widespread conversion to switched mode power supplies, transformers were used as the direct means to reduce the line voltage to the level needed for the electronic equipment power supply. In this application, shields prevent transients from coupling through the capacitance that exists between the transformer primary and secondary windings. Transients coupled to the transformer secondary could potentially cause disturbances and failures within any connected electronic equipment.

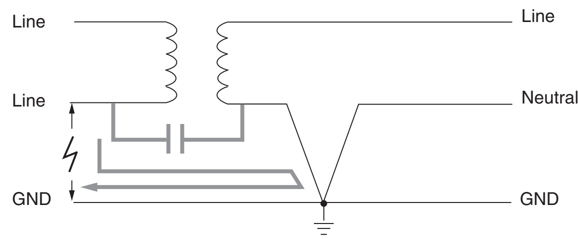
The practice of using shields was also adopted in electrical power applications where it is common to specify electrostatic shields in isolation transformers intended to supply sensitive electronic loads. There is a distinct difference, however, in the two applications. Electrostatic shields prevent differential signals between circuit ground and power ground in electronics. They can capacitively “shunt” away unwanted transients and noise where loads have a different ground than the primary power. See Figure 1.

**Figure 1: Shielding Helps if Secondary is Not Connected to Equipment Ground**




However, most electrical power installations have the secondary side of the transformer grounded to the same ground as the primary source. Solidly connecting the secondary to ground ensures that primary and secondary grounds are the same point on the load side. Neutral grounding returns common-mode transients and impulses back to the primary source without the need for an electrostatic shield. The common ground, not the electrostatic shield, prevents common-mode noise at the secondary. See Figure 2 on page 2.

**Figure 2: Grounded Secondary Prevents Common-Mode Noise**




Misunderstanding the difference between these applications has fostered a fairly large market for electrostatic shielded electrical distribution transformers, even prompting some manufacturers to offer shielding in virtually their entire transformer product line as a “value-added” feature. However, test data has shown that this shielding is not only of very little value in protecting loads, but can possibly promote transfer of transients and disturbances to the load. In other words, shields may not only be of doubtful value in protecting loads, but can actually cause problems.

# Testing

Several brief attempts were made through the years to create universal American National Standards or IEEE standards for transformer shield testing. For various reasons, no agreed upon standards exist at this time. Therefore, test methods are at the discretion of each manufacturer. Decibel wars have ebbed and flowed in the industry, and users and specifiers have had no common ground on which to base competitive claims. Figures 3 and Figures 4 and 5 on page 3 show the various commonly used test methods and range of results.

These tests have common characteristics:

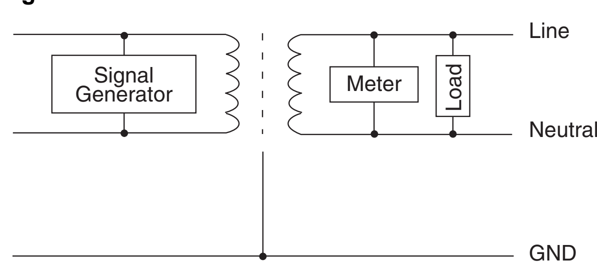
- They are made on non-energized transformers.
- They use only sine wave signal sources, not real impulses and surges.
- There has been little effort made to compare shielded and non-shielded transformers.

Most manufacturers simply pick the best single attenuation value over a reasonable frequency range, ignoring resonant points, poor performance at high frequencies, and other factors that could put them at a competitive disadvantage.

## Insertion Loss Tests

Figure 3 illustrates a typical insertion loss test for line-to-line (transverse-mode) performance of shields. Attenuation values of -30 dB to -60 dB are attainable by varying the amount of load on the secondary. Sometimes capacitance is added to the load to enhance high frequency results. Attenuation in this test is highly sensitive to frequency, so claimed attenuation values are often the best number over the tested frequency band.

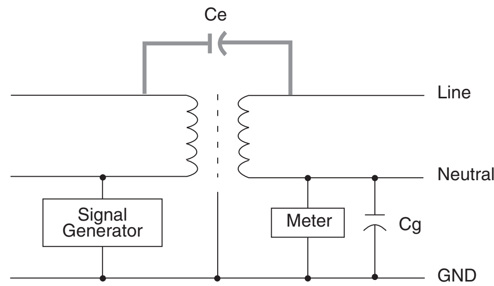
**Figure 3: Insertion Loss Test**



## Common-Mode Tests

Common-mode (line-to-ground) testing is similar to filter testing. Unlike filter tests, however, the load impedance is not specified by standards. The relationship between Ce (effective coupling capacitance) and Cg (ground capacitance) determines signal attenuation. Load type and impedance are not standardized, so any attenuation value is obtainable by varying Cg. Performance claims vary from -50 dB to -152 dB. See Figure 4.

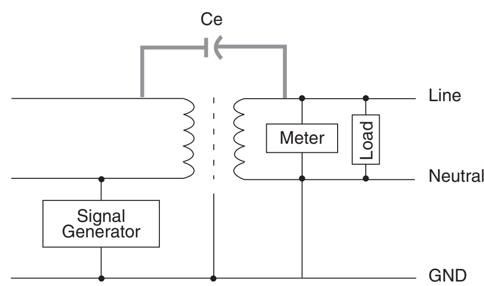
**Figure 4: Common-Mode (Line-to-Ground) Test**




## Common-Mode/Transverse-Mode Tests

In most electrical power installations, the transformer secondary neutral is grounded, making the measurement between neutral and ground illustrated in Figure 4 meaningless. Some manufacturers use this alternate “common-mode/ transverse-mode” measurement (see Figure 5). Since the load type and impedance are not controlled by standards, manufacturers choose values of loading that give them specification advantage. Typical values range from -85 dB to -120 dB with no frequency specified.

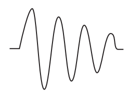
**Figure 5: Common-Mode/Transverse-Mode Test**



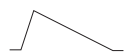
# A Realistic Test Approach

ANSI standards exist which define impulses and frequencies typically found in electrical environments. One of these standard impulse waveforms is a decaying ring wave at a frequency of 150 kHz. This waveform represents typical contact arcing and motor brush noise found in factory electrical environments. Another is an impulse wave, meant to emulate lightning and switching surges from the utility service. It is possible to inject such impulses, as well as discrete frequencies, into energized, loaded transformers to more closely model the performance of transformer impulse and transient reduction in real installations. See Figure 6.

**Figure 6: ANSI Impulse and Frequency Waveforms**



150 kHz ANSI Ring Wave

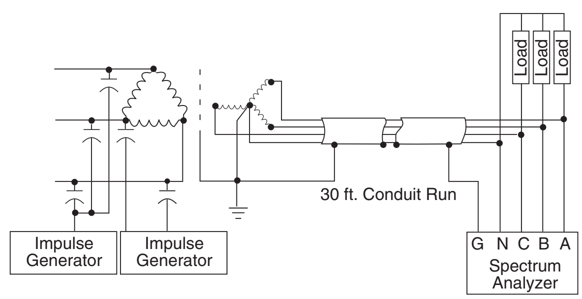


.5 x 50 Microsecond ANSI Impulse Wave

Discrete Frequencies: 20 kHz-10,000 kHz

Schneider Electric constructed two 75 kVA three-phase transformers, 480D - 208Y/120. They were identical except that one incorporated an electrostatic shield between primary and secondary, the other did not. Figure 7 shows a simplified diagram of the test setup. Impulse, ring-wave, and discrete frequency scans showed similar frequency band results.

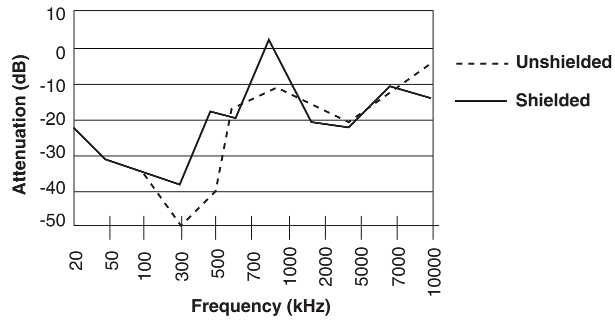
**Figure 7: Square D Test Setup**



## Transverse-Mode Test Results

Over most of the frequency range of 20 kHz to 10 MHz, the unshielded transformer performed better than the shielded version. Of particular interest is the 100 kHz to 500 kHz frequency range, where most impulse and transient energy exists in industrial environments. Transverse-mode impulses are the most damaging in energy content and amplitude. See Figure 8.

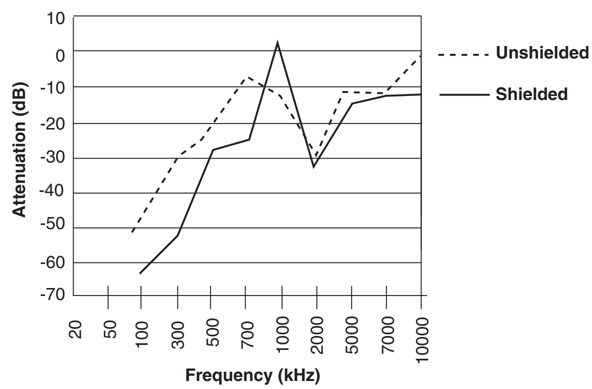
**Figure 8: Transverse-Mode Test Data**




## Common-Mode/Transverse-Mode Test Results

Common-mode/transverse-mode testing (see Figure 9) shows that the unshielded transformer performs marginally better for this type of disturbance. That small advantage is inadequate compensation for the shield's relatively poor performance in transverse mode.

**Figure 9: Common-Mode/Transverse-Mode Data**




## Test Results Summary

The test results demonstrate several important points:

1. Claims about shield performance derived from measurements taken on non-energized transformers appear to be unrealistically exaggerated.
2. Introduction of a shield appears to add unwanted capacitance between transformer primary and secondary. This can cause spurious and sometimes resonant conditions to occur during a transient event, particularly at frequency bands most associated with noise and transients in industrial facilities.
3. Secondary grounding prevents common-mode noise at the transformer secondary. The remaining induced transverse-mode noise is only marginally reduced by shielding.

## Conclusion

The load side neutral is solidly grounded in well over 95% of all transformer installations. That is because the National Electrical Code defines the secondary of a transformer as a separately derived source. The NEC allows only those installations without a neutral to be ungrounded. Although electrostatic shielding should prove beneficial for ungrounded systems, such systems are rare and almost never used for sensitive electronic equipment.

Testing has shown that shielding provides little or no benefit in most electrical installations of distribution transformers. In fact, the test data indicates that shields can actually be detrimental to the system power quality under certain conditions.

Based on the most common uses of distribution transformers and the associated test data, the following are recommended steps when determining the proper transformer specification.

1. Examine carefully the practice of specifying electrostatic shields to ensure proper application. Remember, in many cases, the inclusion of an electrostatic shield does not improve performance.
2. Avoid products which supply shields as a standard practice since this may negatively impact the system power quality. The increase in capacitive coupling can create undesirable consequences.
3. Do not consider shields to be universally proper for protecting sensitive equipment. Consider the events or disturbances in which attenuation is required.
4. Follow proper grounding practices. Grounding has been shown to have the largest power quality impact in common distribution applications.
5. Place isolation transformers as close as possible to sensitive electronic equipment.

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