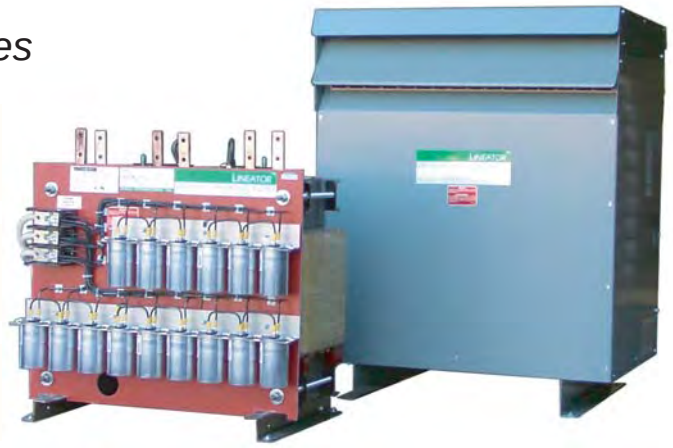
THE LINEATOR™ Patented

Universal Harmonic Filter (UHF)

Energy Efficient 18-Pulse Performance
from standard 6-Pulse Variable Speed Drives



- **Treats all major harmonics generated by Variable Speed Drives and other 3-phase rectifier loads (5th, 7th, 11th, 13th …)**
- **Easily applied to input of a single VSD**
  No need to phase shift against other VSD's
  No need for costly harmonic studies
- **Suitable for application on multiple VSD's provided only VSD's are connected**
- **Will meet IEEE 519 standard for both current and voltage distortion**
- **Input current demand distortion < 8% over entire operating range**
- **Power factor 0.98 lagging to 0.95 leading over the normal operating range**
- **Compatible with engine generators since capacitive reactance is < 15% of rated kVA even under light loads**
- **Will not resonate with other power system components or attract line side harmonics**
- **Suppresses overvoltages caused by capacitor switching and other fast changing loads**
- **Eliminates need for drive isolation transformers, AC line reactors and DC link chokes**
- **Removal of harmonics improves overall system power factor**
- **Saves energy by reducing upstream harmonic losses while operating at > 99% efficiency**
- **Reduces RF Interference generated by VSD**

The use of Variable Speed Drives and other static power conversion equipment has grown rapidly in recent years. With this growth has come concern over the level of current harmonics generated by such equipment. Harmonic currents and the voltage distortion these currents create can have devastating effects on a power distribution system and its connected equipment.

Present methods of harmonic treatment (line reactors, multi-pulsed systems, tuned or broadband passive filters and active filters) are often unreliable, moderately effective or too costly. The innovative LINEATOR™ is a proven advance in the area of passive harmonic mitigation. No other device on the market can meet the most stringent limits of IEEE STD 519 at an equivalent size and cost. When the application calls for a truly cost effective harmonic solution, the LINEATOR™ is the only logical choice.

MIRUS
WE HAVE THE POWER

www.mirusinternational.com lineator@mirusinternational.com

Harmonic Treatment for Variable Speed Drives

The front-end rectifiers of 3-phase, 6-pulse static power convertors (AC-DC), such as those found in variable speed drives, are considered non-linear because they draw current in a non-sinusoidal manner. The current harmonics they generate are predominantly the 5th and 7th with 11th, 13th and other higher orders also present but at lower levels.

Power distribution systems that carry a heavy non-linear load component will often experience problems due to excessive harmonic currents. Problems that can arise include:

- *Power factor correction capacitor failures*
- *Overheating cables, transformers and other distribution equipment*
- *Distortion of the voltage waveform (typically flat-topping) especially when operating on emergency standby generators*
- *False tripping of circuit breakers*
- *Premature failure of motors, generators and other rotating equipment*
- *Misoperation or component failure in PLC's, computers and other sensitive loads*

HARMONIC TREATMENT OPTIONS

There are various methods presently available for treatment of VSD harmonics. Each has its advantages and disadvantages but none can achieve the price/performance level of the LINEATOR™.

Reactors and chokes are a relatively low cost solution but are only moderately effective (Table 1) and their high impedance can introduce troublesome voltage drops.

Conventional **tuned or trap filters**, as their name implies, require tuning to a specific harmonic frequency. Their effectiveness is marginal unless multiple tuned elements are incorporated. Also, they are prone to problems such as resonance with other system components, importation of harmonics from upstream non-linear loads and a leading power factor.

By treating a wider spectrum of harmonics, **broad-band filters** are more effective than tuned filters but can also be more expensive. Although they address some of the issues associated with tuned filters, they are not trouble-free. Specifically, their large capacitor banks create a leading power factor which has been known to cause excitation control problems with generators.

In **multi-pulsed systems**, the drive manufacturer will phase shift between multiple front-end rectifiers to cancel harmonics. Some 18 and 24 pulsed systems can achieve Total Harmonic Current Distortion (THID) of < 8%, but they have a larger footprint, lower efficiency and a higher cost.

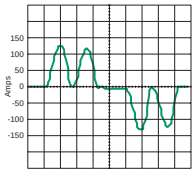
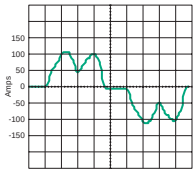
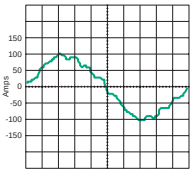
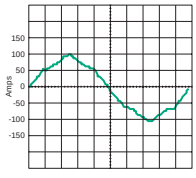
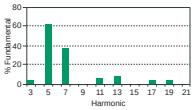
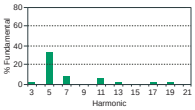
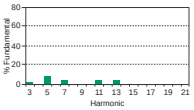
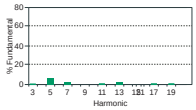
Phase shifting transformers can be a very cost effective method of harmonic treatment but require multiple 6-pulse rectifier loads operating simultaneously. A quasi 12-pulse scheme (ie. cancellation of 5th & 7th harmonics) can be created by phase shifting one VSD against a second similar VSD. 18 and 24 pulse schemes require three and four VSD's respectively.

Active filters treat harmonics by measuring the level of harmonic current present in the system and injecting currents of opposite polarity to cancel them. Excellent performance can be achieved, but reliability is sometimes an issue. Also, high cost and low efficiencies normally makes their use prohibitive.

The LINEATOR™ will treat all of the major harmonics and achieve results previously only attainable through active filtering or multi-pulse systems 18 or higher. Table 1 shows actual test results comparing the harmonics generated by a 60 HP VSD with various passive harmonic treatments. The LINEATOR™ reduced current distortion by more than 10x and brought the power factor to unity. The net result is essentially a linear load, with harmonics no longer at a level for concern.

Compare Performance !

Table 1: Performance comparison of various passive harmonic treatments.

	6-Pulse Rectifier, PWM VSD	With 3% AC Line Reactor	12-Pulse VSD	With MIRUS LINEATOR™
Input Current Waveform				
Input Current Harmonic Spectrum				
Total Harmonic Current Distortion (THID)	72.9%	35.6%	9.3%	5.8%
Power Factor	0.79 Lag	0.90 Lag	0.98 Lag	0.99 Lag

Advantages of the LINEATOR™ *over other Passive Filters*

The LINEATOR™ is a purely passive device consisting of a revolutionary new inductor combined with a relatively small capacitor bank. It's innovative design achieves cancellation of all the major harmonic currents (including AM Band RFI) generated by VSD's and other similar 3-phase, 6-pulse rectifier loads. The resulting THID is reduced to < 8% and often as low as 5%. Although referred to as a filter, the LINEATOR™ exhibits none of the problems that plague conventional filters.

HARMONICS FROM OTHER SOURCES

As a parallel connected device, the conventional trap filter has no directional properties. It therefore, can easily be overloaded by attracting harmonics from upstream non-linear loads. The LINEATOR™, on the other hand, will present a high impedance to line side harmonics eliminating the possibility of inadvertent importation and overloading.

SYSTEM RESONANCE

At frequencies below its tuned frequency, a conventional filter will appear capacitive. This capacitance has the potential of resonating with the power systems natural inductance. When a filter is tuned to a higher order harmonic, such as the 11th, it could easily resonate at a lower harmonic frequency, such as the 5th or 7th. *The natural resonance frequency of the* LINEATOR™ *is below that of any predominant harmonic, therefore inadvertent resonance is avoided.*

LEADING POWER FACTOR

The large capacitor banks in both trap filters and broadband filters present a capacitive reactance to the system, especially under light loads. This can be a beneficial feature where inductive loads require a compensating reactance to improve a low displacement power factor. However, in most VSD applications, displacement power factor is quite high even though overall power factor is low due to the harmonic content. Compensation for inductive loads is not necessary and, in fact, can cause problems especially when supplied by an emergency standby generator. To address this, more sophisticated filters will be equipped with a mechanism for switching out the capacitors under light loads, increasing cost and complexity. Even under no load conditions, the capacitive reactance (KVAR) of the LINEATOR™ remains below 15% of it's kVA rating. This ensures compatibility with engine generators, without the need to switch out capacitors.

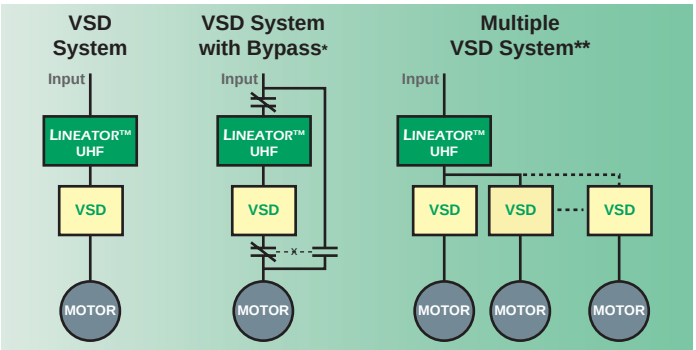


Figure 1: Single line diagrams of VSD systems with the **LINEATOR™.**

HARMONIC DISTORTION REDUCTION

The filtering effectiveness of a trap filter is dependent upon the amount of harmonics present at untuned frequencies as well as the residual at the tuned frequency. To obtain performance better than 15% THID, multiple tuned branches are often required. Broadband filters claim < 12% THID but require relatively large capacitor banks to achieve this. Even larger capacitors are required if further reduction in THID is desired. **The** LINEATOR™ **will reduce current distortion to < 8% and often achieves levels near 5% THID at full load.**

Eliminates Need for Drive Isolation Transformers

Poor field experiences have led many engineers to specify drive isolation transformers on every VSD installation. The belief is that by 'isolating' the drive from the supply many power related problems are eliminated. Although the inherent impedance and galvanic isolation of a drive isolation transformer will provide some protection for the drive against power induced problems, such as capacitor switching overvoltages and high frequency noise, it does very little to protect the supply bus from the harmonics generated by the drive. ***The high let-through impedance of the*** LINEATOR™ ***will provide many of the same benefits as the drive isolation transformer, while also dramatically reducing the harmonics injected into the power system by the drive. It accomplishes this in a much smaller footprint and with improved efficiency. Therefore, the use of the*** LINEATOR™ ***will eliminate the need for drive isolation transformers. In addition, any upstream transformer providing voltage transformation will not need a K-factor rating.***