



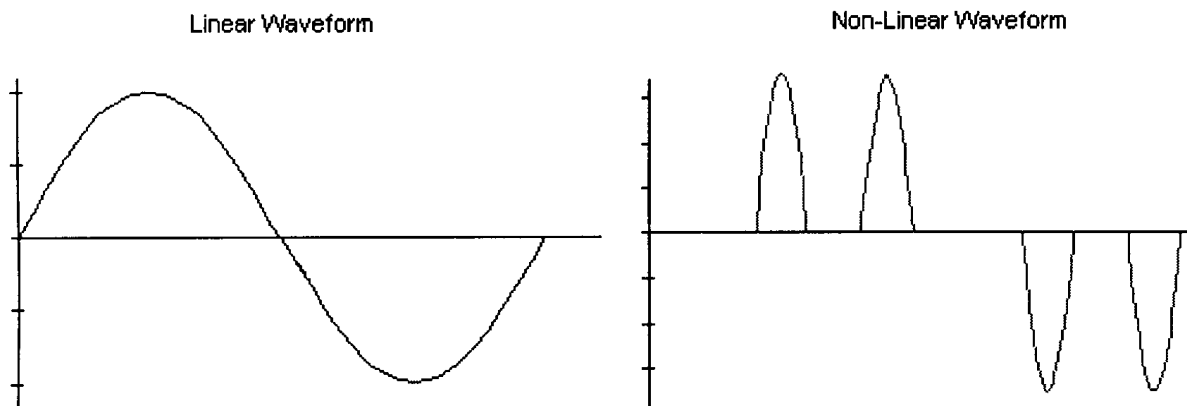
YASKAWA

**Minimizing Total Harmonic Distortion Values.** Modern technology, incorporating sensitive components, present new challenges for plant managers and engineers. For example, widespread use of SCR Rectifiers and Diode Rectifiers used in the power conversion section of Adjustable Frequency Drives (AFDs), Computers, Copiers, solid state lighting ballasts, etc., have raised concerns regarding power quality and its role in harmonic distortion.

When discussing power quality it is important to relate the type of electrical waveforms present in the electrical power system. Electrical waveforms are either linear (sinusoidal) or non-linear (non-sinusoidal). Figure 1 illustrates the two waveform types. A linear waveform is commonly referred to as a “sinewave”, and is simple to describe mathematically; a non-linear waveform is not.

Voltage and current waveforms are closely tied to harmonic distortion. **Every wave shape has a Total Harmonic Distortion (THD) value.** With this in mind, it is up to the end-user to specify what, if any, harmonic distortion levels can be tolerated at the service entrance of the building.

For example, a 1000 kVA building transformer at a voltage of 460 Volts and 5% impedance is used in conjunction with 850 total HP of VFD load. Applying the IEEE519-92 standard to this power system will set the total harmonic current limits to **8%** and total harmonic voltage limits to **5%**. The objectives of the current limits are to limit the maximum individual frequency voltage harmonics to 3% of the fundamental and the voltage THD to 5% for systems.



*Figure 1. Example of Linear and Non-Linear Waveforms*



## Minimizing Total Harmonic Distortion Values

The three commonly used methods to combat power line distortion are: Baseline VFD, Input Line Trap Filter, and 12 Pulse Transformer.

### • 12 Pulse Transformer Design

Using a 12 Pulse Transformer configuration will meet power quality specifications such as IEEE519-92. It is important to note that the majority of installations do not need cancellation of harmonics in the power system. If the transformer is not fully loaded, the transformer should have enough capacity to provide clean power to all equipment.

A 12 Pulse Transformer is able to meet the IEEE519-92 or THD limits because of its unique capability to utilize two input rectifiers in a drive to realize true cancellation of the 5th and 7th harmonic. This is accomplished by **phase manipulation** - electrically shifting the input power to the drive. Since many Yaskawa ac drives have two six pulse rectifiers as standard, one six pulse rectifier just needs to be shifted by 30° in respect to the second six pulse rectifier.

To insure maximum cancellation, it is important to properly balance the impedance of the transformer secondary. One drawback to standard phase shift transformer, is that the delta and wye configurations have different impedance. This in turn causes one of the diode sections to draw more current; the result being inadequate harmonic cancellation.

The Yaskawa 12 Pulse Transformer uses a different power transformation technique (see Figure 2) to insure maximum impedance balance, and therefore maximum harmonic cancellation. Using the dual diode input (standard in many GPD drives) with a 12 Pulse Transformer can reduce current distortion levels by 90%.

The transformer effectively eliminates the 5th and 7th harmonic in the transformer windings. Since the 5th and 7th harmonic contribute to approximately 90% of the harmonic spectrum, very high density packaging of drives to transformer size can be achieved.

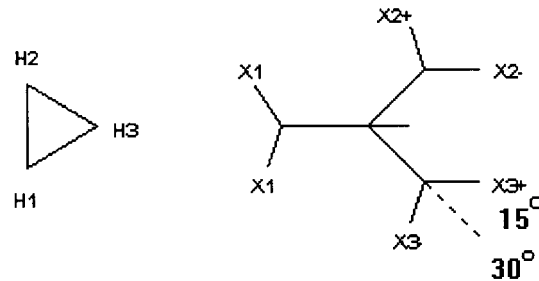


Figure 2. Transformer Vector Diagram

• **Baseline Adjustable Frequency Drive:** Voltage distortion is very low, comparable to what a 3 phase induction motor will produce. Current distortion varies with system characteristics. If the transformer impedance is very high, the current distortion will be relatively low (soft system). If the transformer impedance is very low, the current distortion will be relatively high (stiff system). In the majority of applications no additional hardware is needed to combat harmonic distortion.

• **Input Trap Filter:** It is possible to design a filter that will specifically reduce the harmonics within the harmonic spectrum. In most cases, trap filters are designed to eliminate the 5th harmonic. Trap filters do this by providing a low impedance path for that harmonic. For example, if the end user has a concern about the 5th harmonic, which will have a frequency of 300 Hz on 60 cycle power, a filter can be installed that will trap all 300 Hz frequencies. Unfortunately, in many instances the trap filter will sink currents from different parts of the plant. This may cause random circuit breaker tripping and blown fuses.



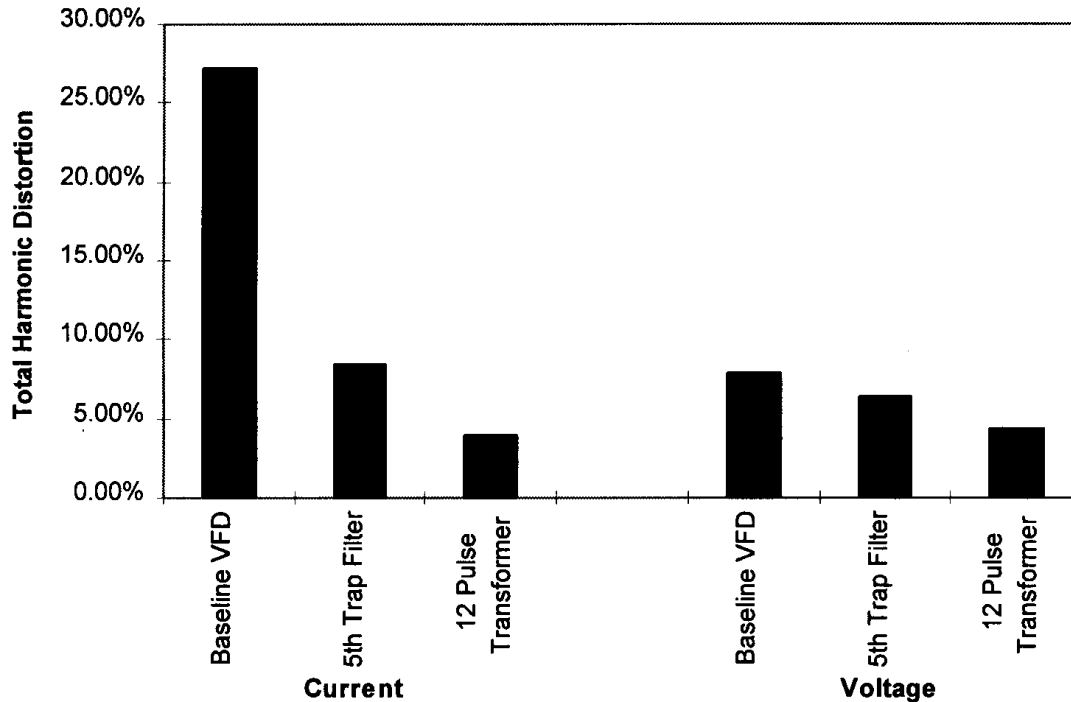
## *Minimizing Total Harmonic Distortion Values*

Table 1 summarizes the harmonic multiples in question. It is important to note that the 12 Pulse Transformer allows the system to meet both current and voltage distortion limits!

**Table 1. Harmonic Reduction Comparison**

Harmonic	Baseline VFD		Trap Filter		12 Pulse XFMR	
	Current	Voltage	Current	Voltage	Voltage	Current
5th	25.12%	6.28%	4.59%	5.22%	2.22%	3.66%
7th	8.66%	3.03%	4.67%	2.03%	1.40%	1.38%
11th	5.32%	2.92%	4.69%	2.58%	2.52%	1.66%
13th	1.85%	1.20%	1.76%	1.15%	1.17%	0.91%
17th	1.51%	1.28%	1.18%	1.01%	0.73%	0.63%
19th	0.92%	0.88%	0.91%	0.86%	0.73%	0.68%
<b>TDD</b>	<b>27.21%</b>	<b>7.81%</b>	<b>8.38%</b>	<b>6.41%</b>	<b>3.87%</b>	<b>4.44%</b>

**Total Harmonic Distortion for Current and Voltage**





**Other commonly used methods to control Power line harmonics include;**

- **DC Link Choke:** Reduces current distortion by approximately 45%. A DC Link Choke is simply an inductor located in the ripple filter circuit, placed before the drive's DC Bus Capacitors. In some drives it is standard, in others it may be an option.
- **Three Phase Input Reactor:** A 3% input reactor will reduce the current distortion by approximately the same percentage as a DC Link Choke. A reactor simply adds impedance to the system which will slow down the di/dt of the current flow into the drive capacitors. The result is a lower current distortion level. This is the same as having a high impedance transformer in the system. It is important to note that there is a point of diminishing returns regarding impedance and current distortion levels. Through laboratory testing, after 7% input impedance, the distortion levels do not drop any lower.

**Conclusion.** It is important to note that use of an IEEE Standard is wholly voluntary. The scope of the standard is to establish **GOALS** for the design of electrical systems that include both linear and non-linear loads. This recommended practice recognizes the responsibility of the utilities to provide users with close to a sine wave of voltage. Utilities are concerned with providing their customers the cleanest voltage waveforms possible. If current harmonics are a problem, the result is increased voltage distortion. IEEE's standards on voltage distortion are very clear and accurate. If voltage distortion exceeds 5% THD, the power factor of the building will be reduced. Utility data can be used to determine if any corrective procedures should be instituted to mitigate poor power factor penalty charges. *One important issue not to overlook is if power factor is a problem, it can result in higher utility bills.*