Harmonic reduction methods

Overview

There are several basic methods for reducing harmonic voltage and current distortion from nonlinear distribution loads such as adjustable frequency drives (AFDs). Following is a description of each method, along with each method's advantages and disadvantages.

Harmonic reduction methods

No method used

Assuming an AFD with a six-diode input bridge, and no line reactor, DC choke, or filter applied, IEEE® 519 1992 guidelines may not be met even if the total connected AFD loads are less than 10%. Because many AFDs require a minimum 1–3% input impedance, the AFD requirements may not be met without a line reactor or additional impedance.

Note: The SVX9000 comes standard with a nominal 3% input impedance, except for the Compact NEMA® Type 1 design in the M3b enclosure.

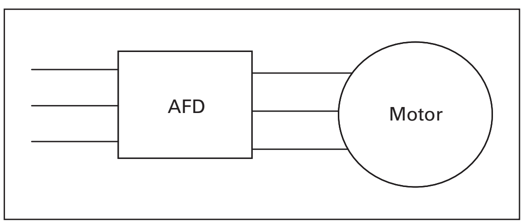

Figure 1. No Method Used

Advantages

- No added cost
- Easy to package
- Easy to sell
- Easy to apply

Disadvantages

- Potentially high levels of harmonic current and voltage distortion
- AFD is more susceptible to damage caused by line transients
- AFD impedance requirements may not be met

DC choke

This is simply a series inductance on the DC side of the semiconductor bridge circuit on the front end of the AFD. In many ways, the DC choke is comparable to an equivalent AC-side line reactor, although the %Total Harmonic Distortion (THD) is somewhat less. The DC choke provides a greater reduction primarily of the 5th and 7th harmonics. On higher order harmonics, the line reactor is superior, so in terms of meeting IEEE guidelines, the DC choke and line reactor are similar. If a DC choke (or line reactor) is applied on all AFDs, it is possible to meet IEEE guidelines where up to 15% to 40% of system loads are AFDs, depending on the stiffness of the line, the amount of linear loads, and the value of choke inductance. A harmonic analysis is required to guarantee compliance with guidelines.

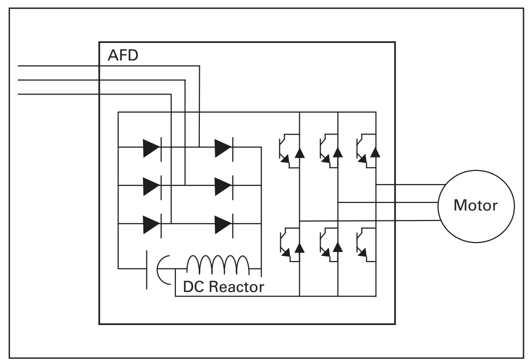

Figure 2. DC Choke

Advantages

- Packaged integrally to the AFD
- Can provide moderate reduction in voltage and current harmonics
- Less voltage drop than an equivalent line reactor

Disadvantages

- Less protection than other methods for the AFD input semiconductors
- May not reduce harmonic levels to below IEEE 519 1992 guidelines
- Impedance is typically fixed by design (not selectable)
- Not available as an option for most AFDs, including the SVX9000

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Line reactor

A line reactor is a three-phase series inductance on the line side of an AFD. If a line reactor is applied on all AFDs, it is possible to meet IEEE guidelines where up to 15% to 40% of system loads are AFDs, depending on the stiffness of the line and the value of line reactance. Line reactors are available in various values of percent impedance, most typically 1–1.5, 3, and 5%.

Note: The SVX9000 comes standard with a nominal 3% input impedance, except for the Compact NEMA Type 1 design in the M3b enclosure. A harmonic analysis is required to guarantee compliance with guidelines.

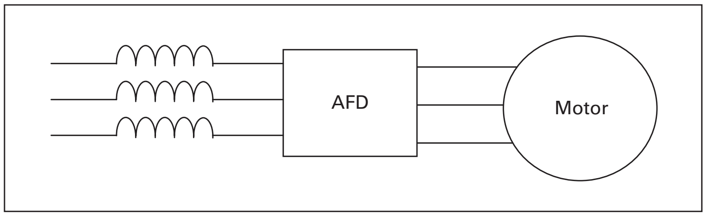

Figure 3. Line Reactor

Advantages

- Low cost
- Can provide moderate reduction in voltage and current harmonics
- Available in various values of percent impedance
- Provides increased input protection for AFD and its semiconductors from line transients

Disadvantages

- May require separate mounting or larger AFD enclosure (for SVX9000 if more than 3% is required)
- May not reduce harmonic levels to below IEEE 519 1992 guidelines

12-pulse converters

A 12-pulse converter incorporates two separate AFD input semiconductor bridges, which are fed from 30° phase shifted power sources with identical impedance. The sources may be two isolation transformers, where one is a delta/wye design (which provides the phase shift) and the second a delta/delta design (which does not phase shift). A line reactor of equal impedance to the delta/wye transformer may also be used in lieu of the delta/delta transformer.

The 12-pulse arrangement allows the harmonics from the first converter to cancel the harmonics of the second. Up to approximately 85% reduction of harmonic current and voltage distortion may be achieved (over standard 6-pulse converter). This permits a facility to use a larger percentage of AFD loads under IEEE 519 1992 guidelines than allowable using line reactors or DC chokes. A harmonic analysis is required to guarantee compliance with guidelines.

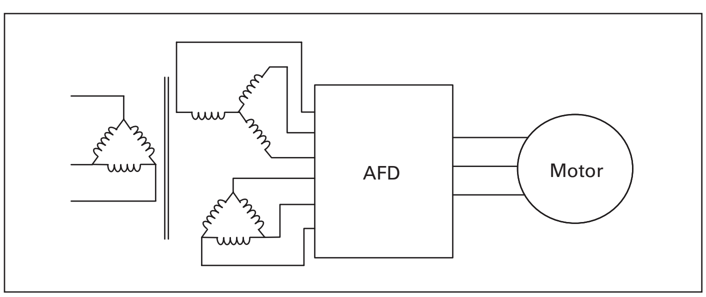

Figure 4. 12-Pulse Converter

Advantages

- Reasonable cost, although significantly more than reactors or chokes
- Substantial reduction (up to approx. 85%) in voltage and current harmonics
- Provides increased input protection for AFD and its semiconductors from line transients

Disadvantages

- Impedance matching of phase-shifted sources is critical to performance
- Transformers often require separate mounting or larger AFD enclosures
- May not reduce distribution harmonic levels to below IEEE 519 1992 guidelines
- Cannot retrofit for most AFDs

12-pulse distribution

This is similar to a 12-pulse converter, on a macro scale. If two AFDs of equal horsepower and load are phase shifted by feeding one AFD from a delta/wye transformer, and feeding the second through a delta/delta transformer or a line reactor of equivalent impedance, performance similar to 12-pulse may be achieved. The cancellation will degrade as the loads vary from AFD to AFD, although as the load on a single AFD decreases, the individual distortion contribution percentage decreases, resulting in less of a need for cancellation.

It is possible for a facility with a large number of AFDs to feed two halves of the distribution from phase-shifted transformers, yielding a large reduction in harmonic levels for minimal cost, and allowing a higher percentage of AFD loads under IEEE 519 1992 guidelines. A harmonic analysis is required to guarantee compliance with guidelines.

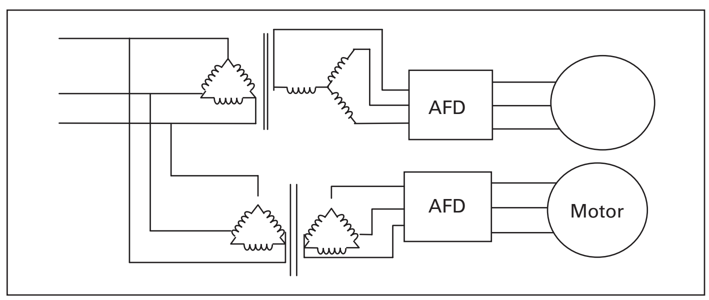

Figure 5. 12-Pulse Distribution

Advantages

- Cost may either be low or high depending on implementation
- Provides substantial reduction (50–80%) in voltage and current harmonics
- Provides increased input protection for AFD and its semiconductors from line transients

Disadvantages

- Cost may be low or high depending on implementation
- Impedance and load-matching of phase-shifted sources is critical to performance
- Transformers will require separate mounting
- May not reduce harmonic levels to below IEEE 519 1992 guidelines

Harmonic trap filters

Harmonic trap filters are usually used in conjunction with a line reactor, and are usually placed on individual AFD loads. They are typically an L-C filter installed in a shunt arrangement on the line side of the AFD, and are tuned somewhat below the 5th harmonic, which is the largest component of harmonic distortion. A significant amount of 7th harmonic distortion will also be absorbed. Additional filters tuned to higher order harmonics may also be used.

More care is needed with the application of harmonic trap filters than with other methods, because they will tend to try to filter the entire distribution system of harmonic components. If additional AFD or nonlinear loads are added without filtering, the previously installed filters may become overloaded (they are generally fused for protection). The line reactor is used in conjunction with the filter to minimize the possibility of this occurring and to enhance filter performance. A harmonic analysis is required to guarantee compliance with guidelines.

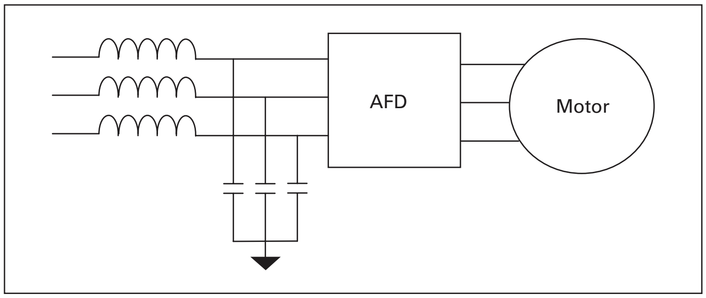

Figure 6. Harmonic Trap Filters

Advantages

- Allow a higher percentage of AFD system loads than line reactors and chokes

Disadvantages

- High cost
- Separate mounting required
- May not reduce harmonic levels to below IEEE 519 1992 guidelines
- Care is needed in application to ensure that the filter will not become overloaded
- Distribution changes, such as adding AFDs, could lead to overloading

Broadband filters

These filters are similar to trap filters, but have some major design differences. As trap filters are connected in parallel to the AFD, broadband filters are connected in series with the AFD and carry the full AFD current. This difference provides added protection for the input power section of the AFD. Broadband filters require no tuning, improve power factor for the system, and minimize all harmonic frequencies, including the 3rd harmonic. Additionally, they avoid system resonance and importation of outside harmonics.

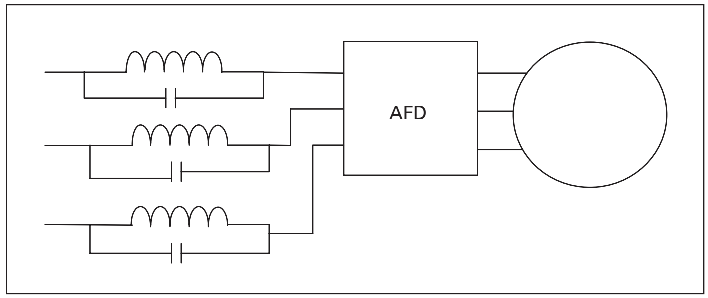

Figure 7. Broadband Filters

Advantages

- Allow a higher percentage of AFD system loads than line reactors and chokes
- Provide increased input protection for AFD and its semiconductors from line transients
- Provide added protection for AFD input power section
- Provide system power factor correction

Disadvantages

- High cost
- Separate mounting required
- May not reduce harmonic levels to below IEEE 519 1992 guidelines
- Could result in leading power factors at during lightly loaded conditions
- Require modification to match with an AFD using internal line reactors, such as the SVX9000

Clean power (18-pulse converter)

This method is similar to 12-pulse converters, although instead of using two phase-shifted power sources and semiconductor bridges, three are used. Eaton uses a specially wound autotransformer (differential delta) and 18-input semiconductors. When this arrangement is used, over 90% of harmonic currents are canceled (typical total harmonic distortion of 2–3%).

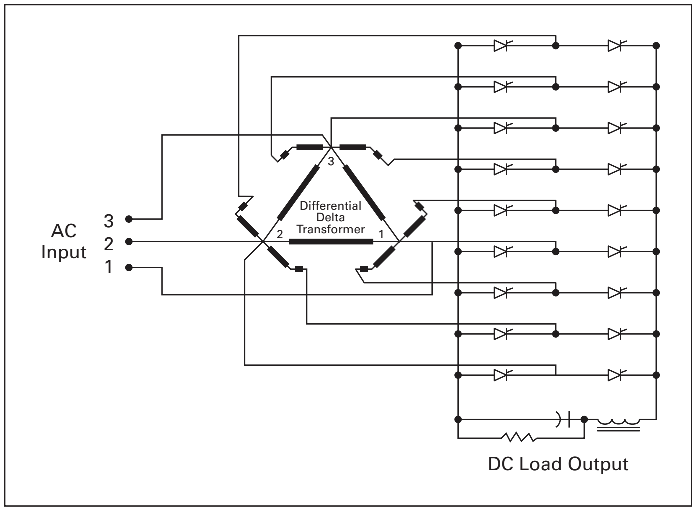

Figure 8. Clean Power (18-Pulse Converter)

Advantages

- Virtually guarantees compliance with IEEE 519 1992
- Provides increased input protection for AFD and its semiconductors from line transients
- Up to four times the harmonic reduction of 12-pulse methods
- Smaller transformer than isolation transformer used in 12-pulse converter

Disadvantages

- Can be more expensive than other methods (for up to four times the harmonic reduction of 12-pulse methods)
- Larger and heavier magnetics than some other methods

Active filters

This method uses sophisticated electronics and power section IGBTs to inject equal and opposite harmonics onto the power system to cancel those generated by other equipment. These filters monitor the nonlinear currents demanded from nonlinear loads (such as AFDs) and electronically generate currents that match and cancel the destructive harmonic currents. Active filters are inherently non-resonating and are easily connected in parallel with system loads.

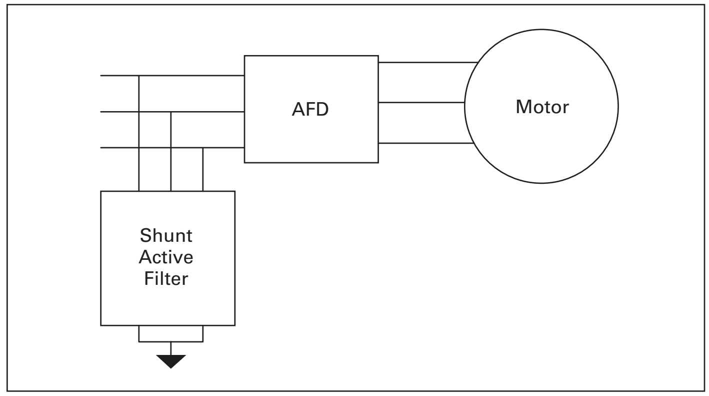

Figure 9. Shunt Active Filter

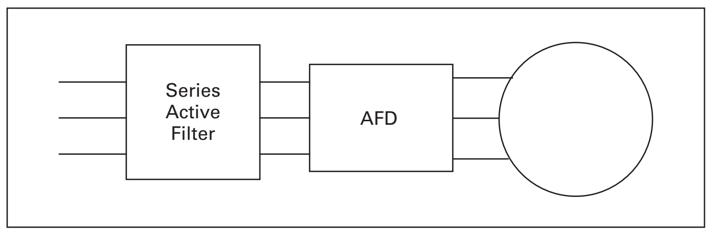

Figure 10. Series Active Filter

Advantages

- Guarantee compliance with IEEE 519 1992 if sized correctly
- Harmonic cancellation from the 2nd to 51st harmonic
- No series connection provides easy installation with no major system rework
- Provide VAR currents, improving system power factor

Disadvantages

- Can be more expensive than other methods due to the high performance control and power sections
- The filter's input semiconductors are exposed to line transients

Note: For assistance in the application of AFDs or harmonic reduction methods, or for a free harmonic analysis, contact your local Eaton distributor or representative.

Eaton Corporation
Electrical Sector
1111 Superior Avenue
Cleveland, OH 44114 USA
Eaton.com

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