Low Voltage Drives Harmonic Mitigation Comparison: AC Line Reactors vs. DC Link Chokes

Introduction

This application note is designed to provide an overview of why impedance on the line side of a drive is beneficial in adjustable frequency drives and compares the expected performance of AC line reactors and DC link chokes. In addition, performance testing is presented to provide a harmonic comparison between the two filtering devices using an Eaton drive with a 3% AC line reactor and an Eaton drive with a 5% DC link choke.

Harmonics Background

All drives naturally create harmonics on a system given the nature of the AC to DC rectifier of a drive. These harmonics are created because the drive only draws current when the magnitude of the AC, line to line voltage is higher than the voltage of the DC bus. In Figure 1 below, the current is blue and the time where the AC, line to line input voltage exceeds the DC voltage is designated as I_d. Current is drawn during the crossover point of the phase voltages and results in a humped waveform. This double hump waveform is typical of most drives.

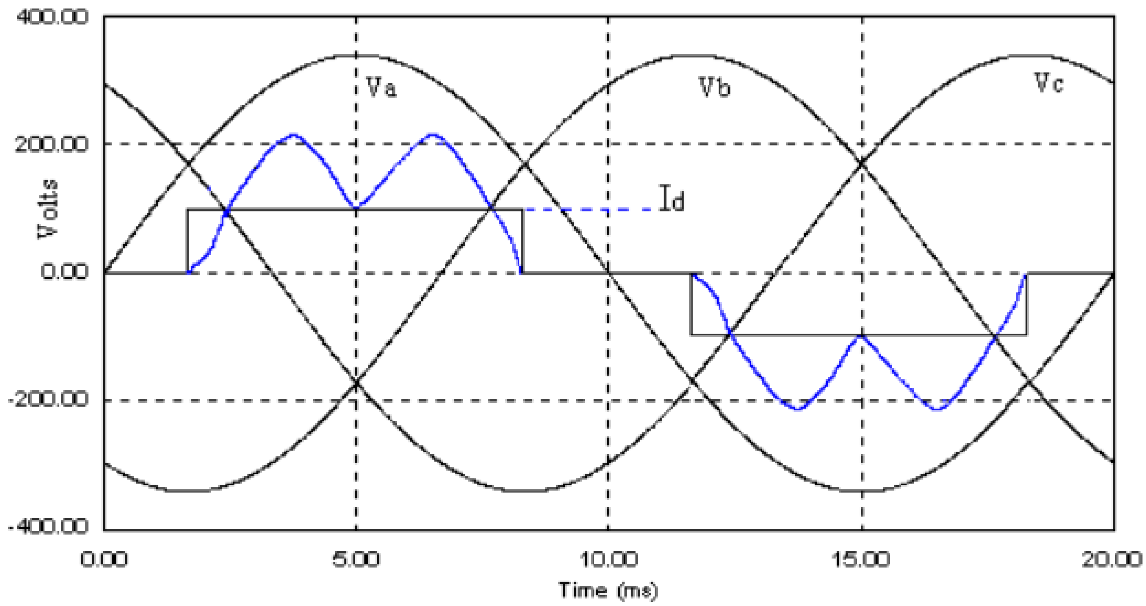

Figure 1: Current draw by drive [1]

Harmonics need to be removed because they can increase the I^2R (power) losses of the system and they can disrupt the proper functioning of other loads on the system as well as potentially damage them. Additionally, utilities often require customers to adhere to IEEE 519 standards of total harmonic distortion (THD). This specifies the amount of harmonics that can be injected back onto the grid. Harmonics that are generated within in a facility, if not properly filtered, will be seen by the utility.

For very small drives, this sinusoidal current draw is not a problem for the utility because the drive is not a significant load on the system. However, for larger horsepower drives additional impedance is normally necessary to remove the impact of these periodic pulses of current. In this regard, the two most common options to choose from are AC line reactors and DC link chokes.

What is a line reactor or choke and how does it affect harmonics?

A choke (or line reactor) is a coil of wire around a magnetic core that creates a magnetic field when current flows through it. This magnetic field increases the impedance of the line and reduces the total harmonic content injected from the drive onto the facilities electrical system. To analyze harmonics, we can examine the harmonic content by breaking down a non-sinusoidal waveform into components. The lower harmonics, like the 5^{th} and 7^{th}, have a larger current magnitude and thus have a larger effect on the total harmonic distortion. This is because the current magnitude is inversely proportional to the harmonic number.

What is an AC line reactor?

AC line reactors are added to the input of the drive and placed in series with the incoming line. They help to mitigate harmonics and because they are between the line and the drive, they are able to act as a buffer for surges and other transients. The intended purpose of a line reactor is not to offer high levels of surge protection and, if greater protection is desired, a dedicated protective device such as a metal oxide varistor (MOV) or a transient voltage surge suppressor (SPD) is a much better solution. The disadvantage of an AC line reactor is that there is a voltage drop across them. This can cause under-voltage trips in systems where the input voltage is not as stable. Additionally, this voltage drop can lower the DC bus voltage and negatively affect the output of the drive. Finally, AC line reactors are normally larger than DC link chokes and typically more expensive, thus increasing the size and cost of the complete drive.

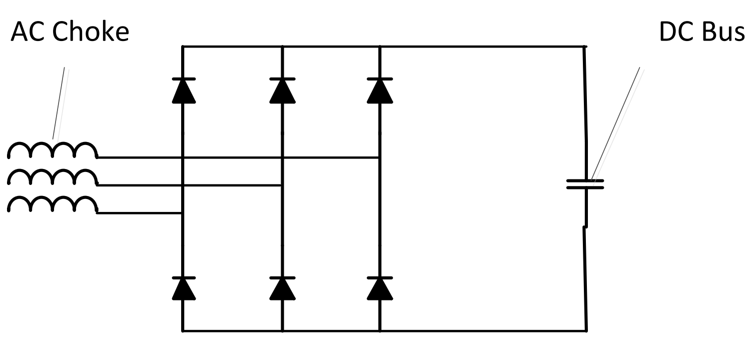

Figure 2: AC Line Reactor Attached before the Rectifier of a Drive

What is a DC choke?

DC link chokes are connected between the diodes and the DC bus. They can be slightly less or slightly more effective at removing harmonics than AC line reactors depending on the order of harmonic being observed. DC link chokes are typically smaller than AC line reactors and they add the necessary impedance for harmonic reduction without a drop in voltage. While the DC link choke does not add any extra buffering from voltage surges seen by the rectifier, it will protect against current surges. The smaller size and no voltage drop provide some benefits over the AC line reactor while providing similar harmonic reductions.

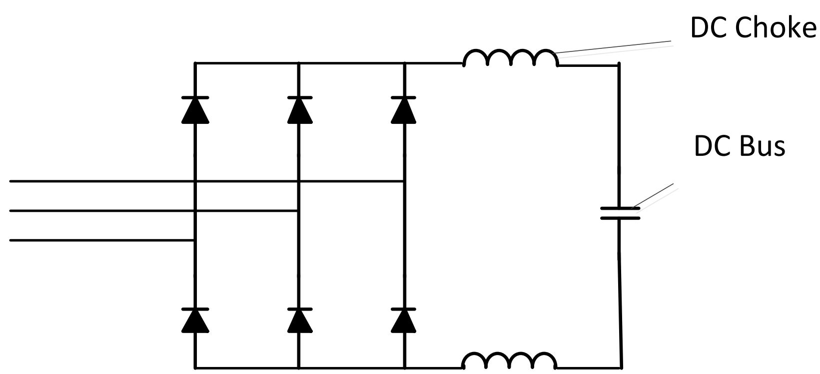

Figure 3: DC Choke Attached to the DC Bus of a Drive

Grounding with AC Line Reactors and DC Link Chokes

It is also important to ground fault currents so that they will not flow through the drive and damage it. AC line reactors inherently do this and, while single coil DC link chokes do not, newer two-coil DC link chokes do. Eaton drives using DC link chokes utilize the newer two-coil designs to provide protection against ground fault conditions.

AC Line Reactor vs. DC Link Choke Performance

To demonstrate the differences between an AC line reactor and DC link choke, the following testing was completed using Eaton drives that utilize the different technologies. The first drive uses a 3% AC line reactor to mitigate harmonics. The second drive uses a 5% DC link choke and MOV surge protection to provide protection on the line side of the drive. There are two critical aspects to consider when comparing these two solutions: the amount of harmonic reduction and the physical size and layout of the drive.

Harmonic Analysis

Full load tests were run to examine the amount of harmonic content at 480V and 30HP for the two Eaton drives (AC line reactor drive and DC link choke drive). As a point of order, the phase to ground voltage is displayed in the figures below. This is equal to the input voltage divided by root(3). The charts below describe the results.

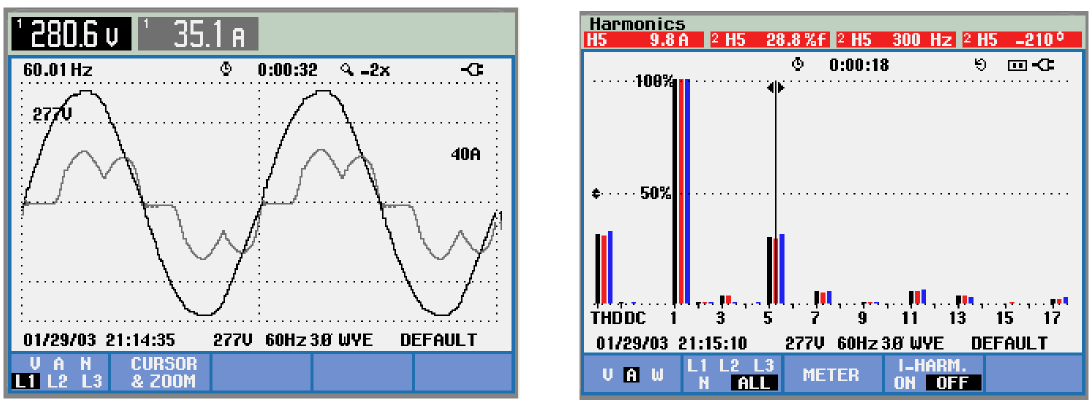

Figure 4: Eaton Drive with 3% AC Line Reactor - Voltage and Current Input (left); Percent Total Harmonic Distortion (right)

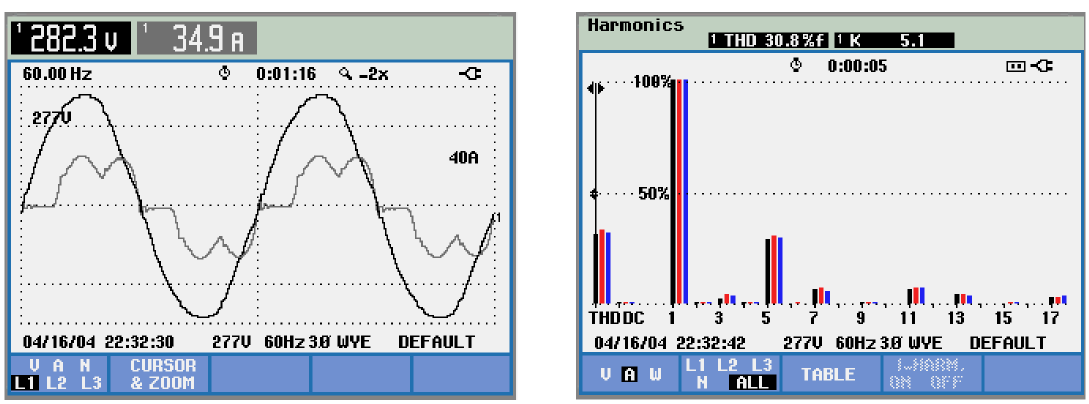

Figure 5: Eaton Drive with 5% DC Link Choke - Voltage and Current Input (left); Percent Total Harmonic Distortion (right)

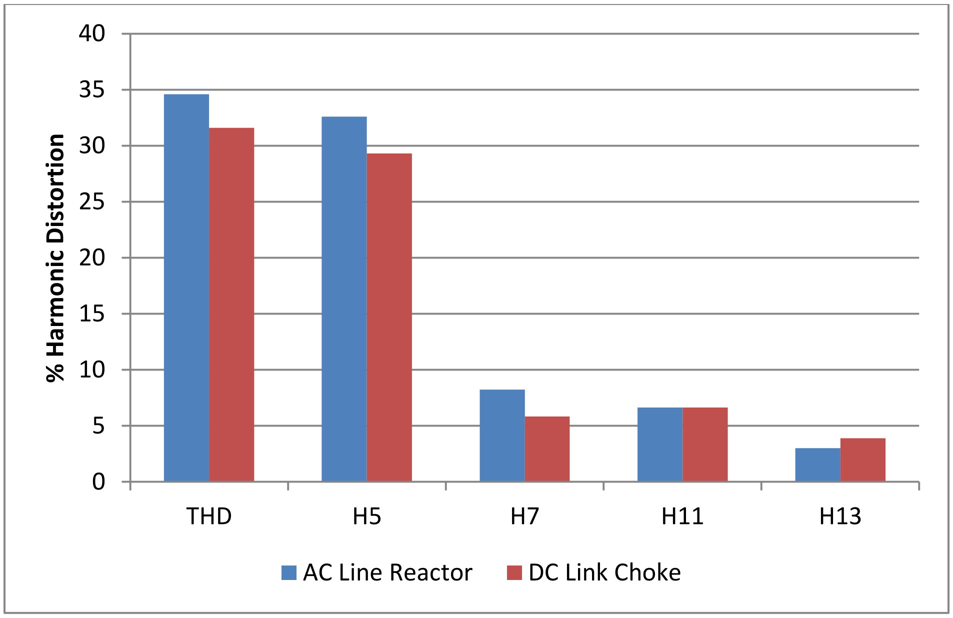

Figure 6: Percent Total Harmonic Distortion (THD) at Various Harmonics for the AC Line Reactor Drive and the DC Link Choke Drive

The harmonic analysis indicates that the Eaton drive with the DC choke exhibits lower % Total Harmonic Distortion (THD) at the 5th and 7th harmonics which are the most detrimental to meeting IEEE 519. The drive with the DC link choke does allow slightly higher %THD at the higher order harmonics (11th and 13th) which, as was stated before, are more of a concern for EMI sensitive areas.

While the DC link choke does provide slightly better %THD than the AC line reactor, the DC link choke is certainly not a cure all for meeting harmonic requirements for a system. Harmonic systems studies are the best option for determining the necessary measures for meeting IEEE 519 as these results may vary with the voltage and power rating of the drives in application. With larger horse power drives, this will typically mean adding a harmonic filter or phase shifting transformer to the drive to truly meet the IEEE 519 requirements.

References

[1] S.*Islam,* “Characteristic and Non-characteristic Harmonics, Harmonic Cancellations and Relevant International Standard in Variable Speed Drives,” Science and Technology, 2002

Additional Help

In the US or Canada: please contact the Technical Resource Center at 1-877-ETN-CARE or 1-877-386-2273 option 2, option 6.

All other supporting documentation is located on the Eaton web site at www.eaton.com/Drives

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