

Effective Harmonic Mitigation with Active Filters

Variable Speed Drive with no Harmonic Mitigation

Industry standard variable speed drives, with 6-pulse diode input rectifiers are the workhorse of industry. They are used primarily for variable speed control of ac induction motors to achieve more efficient process control and energy savings. Industry standard three-phase variable speed drives draw harmonic currents from the three phase voltage source. These harmonics can cause overheating and premature failure of power system equipment such as transformers, cables and circuit breakers. The harmonic currents are at higher frequencies than the 60Hz voltage supply.

	Units	Standalone VFD
VFD Power Rating	HP	500
Input Current	Amps	544
Fundamental 60Hz Current	Amps	513
Harmonic Current	Amps	181
Input Current Distortion	%iTHD	35.2%
Input Voltage Distortion	%vTHD	4.03%

Table 1: Summary of standalone 500HP VFD AC input

A 480V 3-phase power system with a typical 500HP VFD with an internal 3% ac input line reactor is shown in Figure 1. The power system transformer feeding the drive is 2000kVA with 5.75% impedance. This system was simulated to characterize the harmonic input voltage and currents caused by the VFD.

At full load and steady state, the input current and voltage to the 500HP VFD is shown in Figure 2. The input current has a 35% current THD, meaning that harmonic currents are 35% of the 60Hz current. This current distortion in turn produces a voltage distortion across the 2000kVA transformer that powers and may adversely affect other loads on the system. The THD of the voltage in Figure 2 is 4%. A frequency spectrum of the voltage and current is shown in Figure 3. The 5th harmonic current (at 300Hz) is the highest individual harmonic at over 30%.

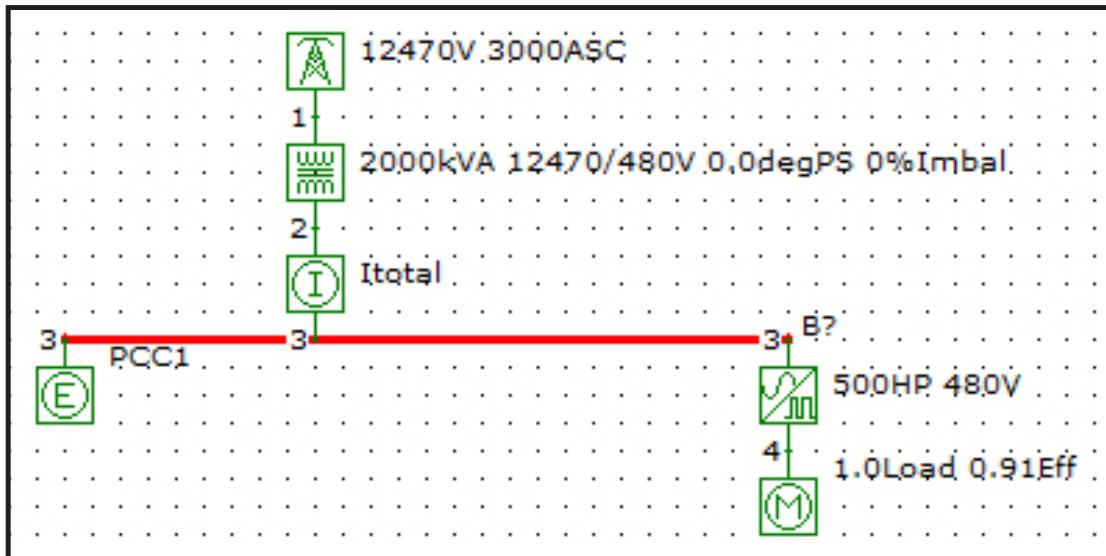


Figure 1: Simulation Model Schematic of a power system with a 500HP VFD and front end active filter

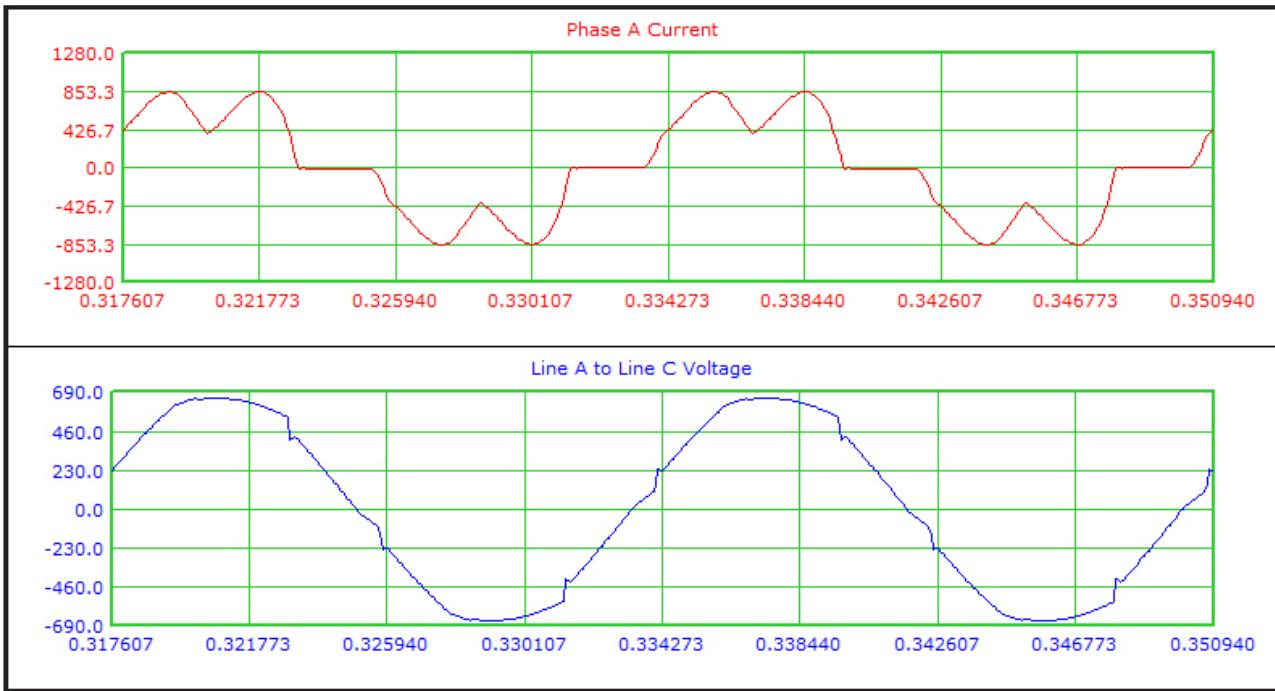


Figure 2: VFD Input current (35% iTHD) and voltage (4% vTHD) time domain waveforms for a standalone VFD without active filter

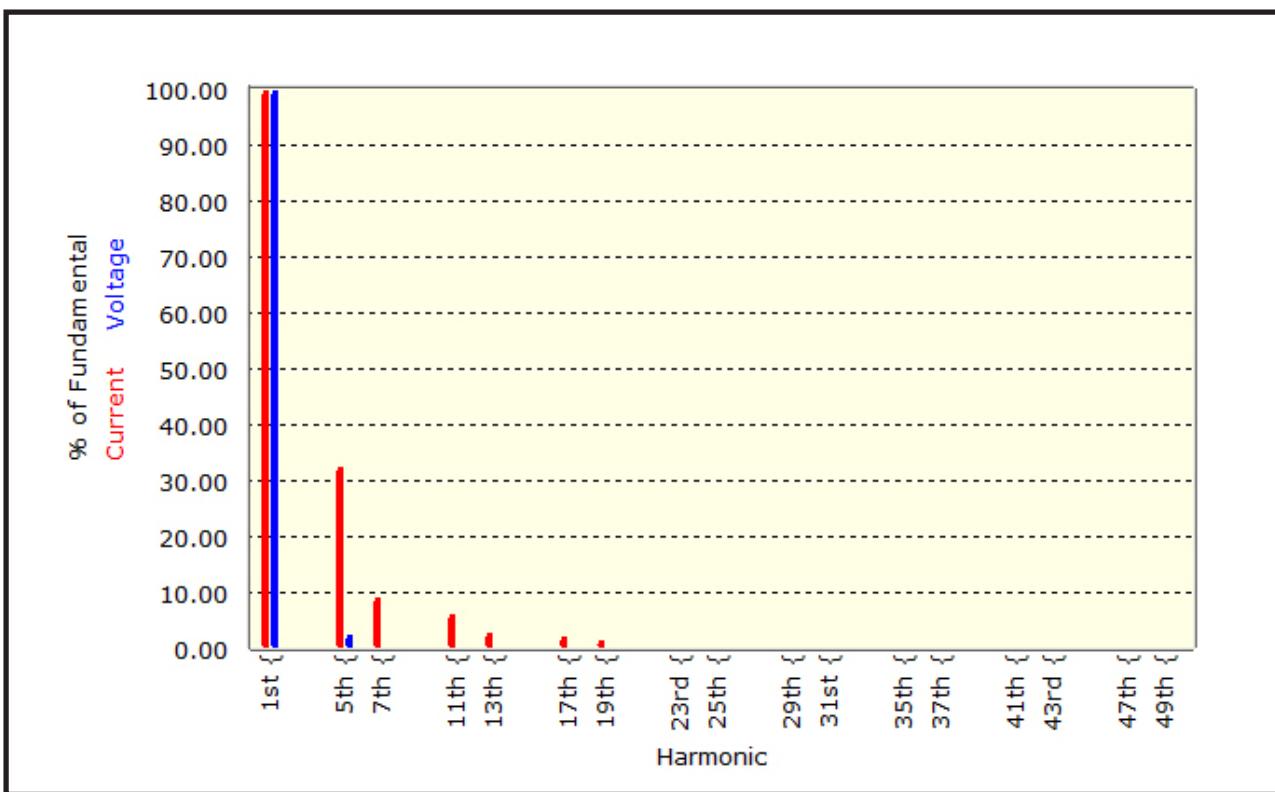


Figure 3: VFD Input current and voltage frequency spectrum for a standalone VFD without an active filter

Variable Speed Drive with an Active Filter

Active filters are highly effective at reducing the harmonic current in the power system to safe levels while allowing the VFD to draw the harmonic currents it needs.

The active filter works by measuring the power system current and injecting the necessary harmonic current to cancel the VFD harmonics. As the filter is an active device it can quickly respond to changes in VFD loading and power system voltage, frequency, unbalance and background voltage distortion conditions. This concept of applying an active filter is illustrated in Figure 4.

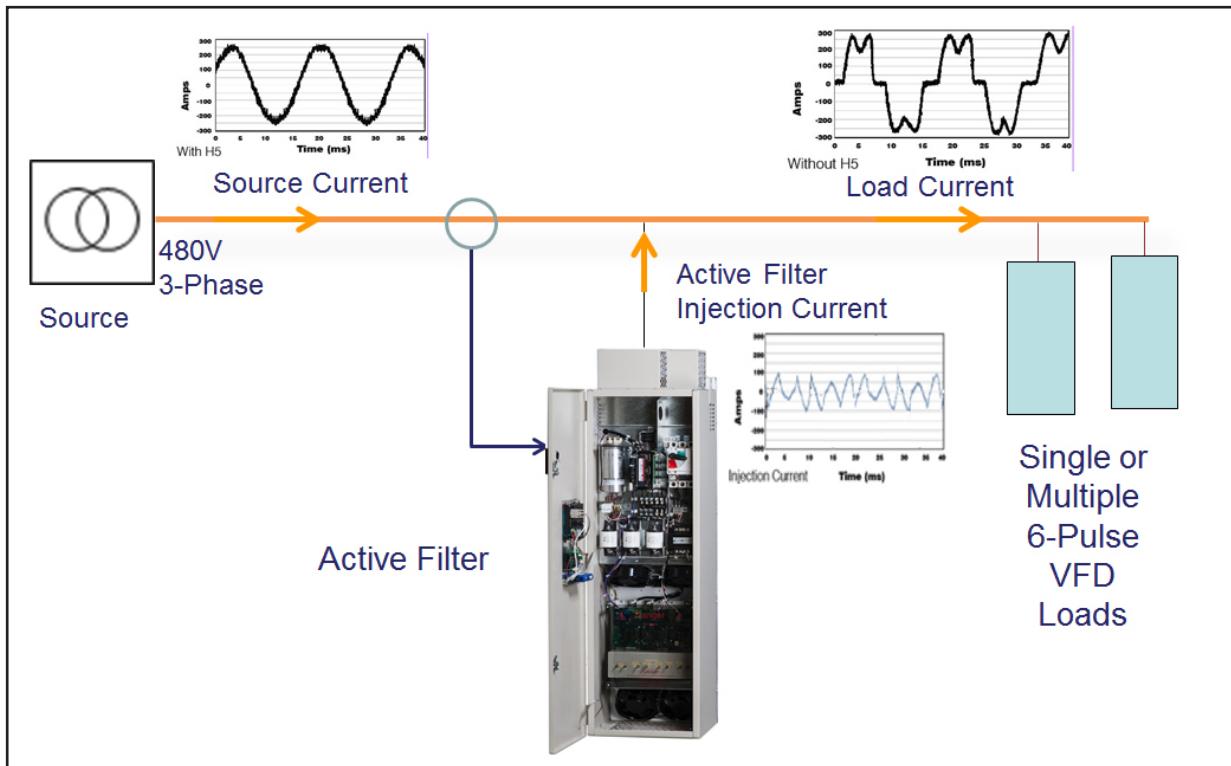


Figure 4: Applying an Active Filter to the electrical power system or input to a VFD

Benefits of Active filters to reduce current THD at the input of VFDs are:

- They can be applied to a whole power system, group of loads or on individual standard 6 pulse VFDs
- MCC Compatible
- Can achieve harmonic current reduction to <5% iTHD
- Monitors the bus, injects counter current to cancel out harmonic currents
- Provides Power Factor Correction if necessary

To determine the reduction of harmonic currents achievable with an active filter the 480V 3-phase power system and 500HP VFD were modeled and analyzed, as shown in Figure 5.

Variable Speed Drive with an Active Filter (cont.)

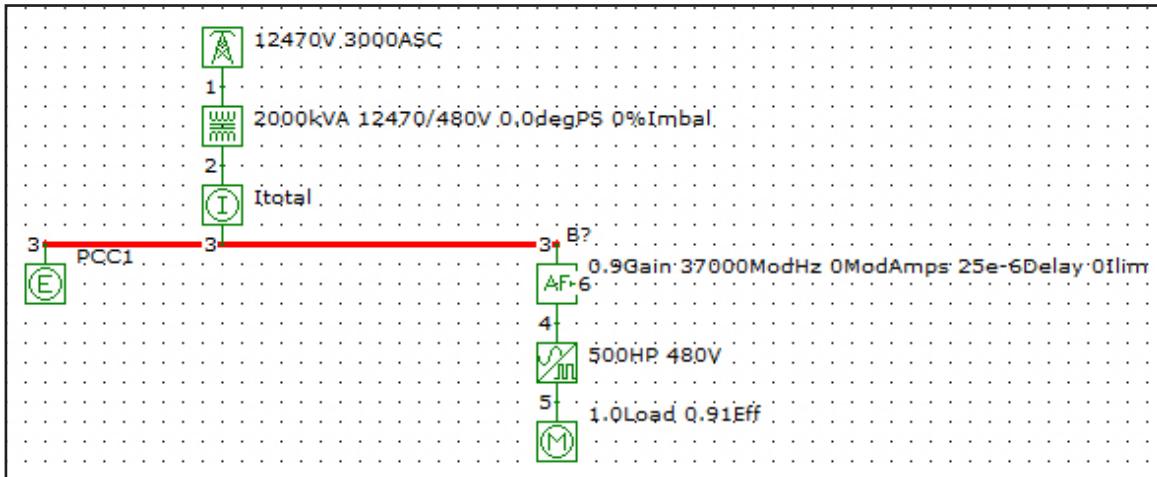


Figure 5: Simulation Model Schematic of a power system with a 500HP VFD and front end active filter

The active filter removes the harmonic currents from the input feed as reflected in the time domain waveforms, shown in Figure 6. The line current and line voltage are near sinusoidal. The current distortion and voltage distortion have been reduced to 3.21% and 0.34% respectively, well under the most stringent IEEE-519 recommended limits. Figure 6 also shows the harmonic current injected by the active filter, which contains higher frequencies than the source 60 Hz. The frequency spectrum of the filtered source current and voltage is in Figure 7, where the peak current component at the 5th harmonic (300Hz) has been reduced to 2.9%.

	Units	Active Filter And VFD
VFD Power Rating	HP	500
Input Current	Amps	496
Fundamental 60Hz Current	Amps	495
Harmonic Current	Amps	15.9
Input Current Distortion	%iTHD	3.21%
Input Voltage Distortion	%vTHD	.34%
Active Filter Injection Current	Amps	226

Table 2: Summary of Active Filter and 500HP VFD AC

Variable Speed Drive with an Active Filter (cont.)

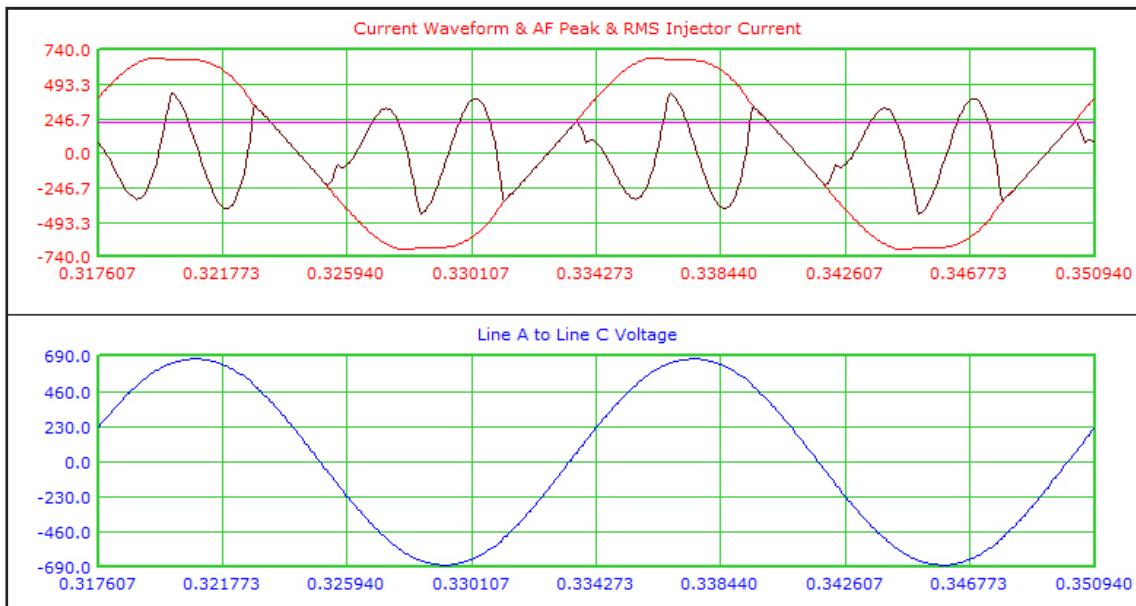


Figure 6: VFD Input current and Active filter injection current, and ac voltage time domain waveforms for a standalone VFD with an active filter

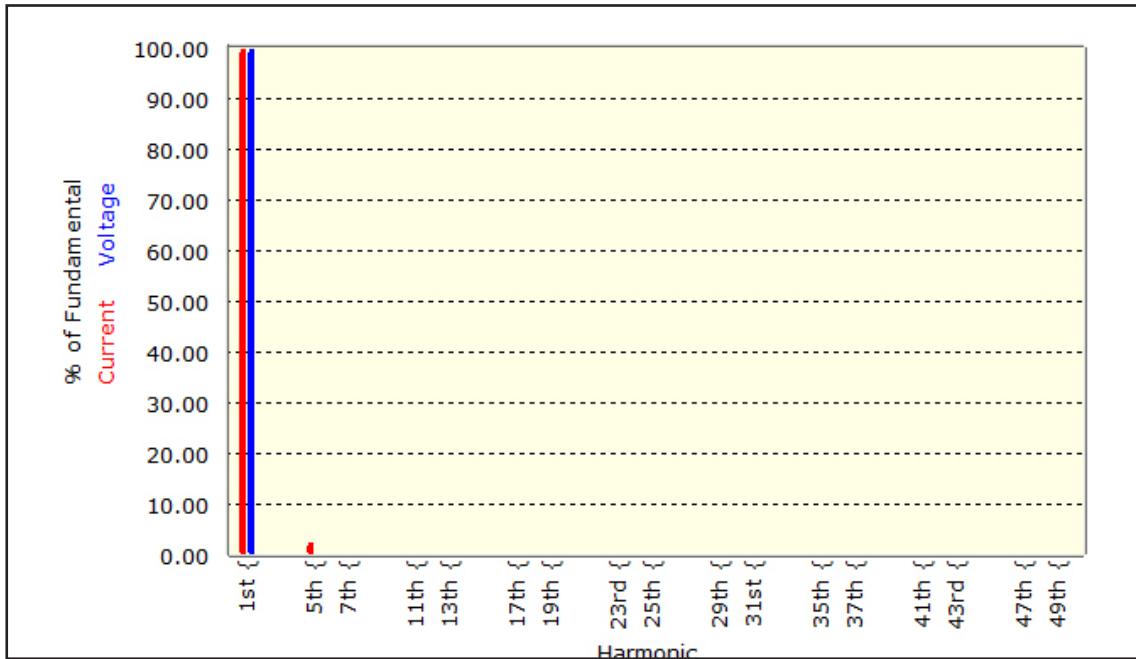


Figure 7: VFD Input current and voltage frequency spectrum for a standalone VFD with an active filter

Summary

An active filter is an effective way to filter the harmonic currents required by VFDs and eliminate the harmonic currents and voltages from the AC source. In the case study presented, the active filter reduced the total RMS currents in the source by almost 10%, while reducing the current distortion from 35% to 3.2% THD. Resultantly, the voltage distortion was reduced from 4% to under 0.5%.

	Units	Standalone VFD	Active Filter And VFD
VFD Power Rating	HP	500	500
Input Current	Amps	544	496
Fundamental 60Hz Current	Amps	513	495
Harmonic Current	Amps	181	15.9
Input Current Distortion	%iTHD	35.2%	3.21%
Input Voltage Distortion	%vTHD	4.03%	.34%
Active Filter Injection Current	Amps	--	226
On a 480V, 60Hz power system with 2000kVA transformer with 5.75% impedance			

Table 3: Summary of 500HP VFD with and without an Active Filter

