How water plant operators can easily meet IEEE 519 harmonic limits

Without overspending on Variable Frequency Drives

Bigger isn't always better: While 18-pulse variable frequency drives can provide total harmonic distortion levels of just 1.98% — less than half the 5% limit set by IEEE 519 — many water treatment operators are choosing more costly 24-pulse drives, wasting money and space.

IEEE 519: Controlling total harmonic distortion — much more cost-effectively

A variable-frequency drive (VFD) is a system for controlling the rotational speed of an alternating current (AC) electric motor by controlling the frequency of the electrical power supplied to the motor. The most common analogy to explain how a VFD works is to compare it to a car's accelerator, which enables drivers to vary the car's speed as needed — instead of controlling the speed using wasteful braking.

With that analogy in mind, imagine buying a new car, finding just the right make and model with all the needed horsepower and options. But your decision is based on the acceleration. One car accelerates from zero to 60 mph in 5 seconds, while the other in 4.2 seconds. The model with the slightly faster acceleration costs $30,000 and uses regular gas, while the second costs $34,800, requires premium gas, and needs more garage space.

Given you want to use the car for 10 years or more, which model do you buy?

This question is essentially what faces many plant decision-makers when they must decide between a 24-pulse variable frequency drives (VFDs) and an equally capable 18-pulse VFD, which can cost less to buy and operate, plus take up less plant real estate "garage space." As plant managers, maintenance engineers, and consulting engineers know, the conversation about the best VFD pulse-type centers around lowering Total Harmonic Distortion (THD) of a VFD system to within acceptable limits, as described in IEEE 519 (Primarily Current Distortion).

IEEE519, first published in 1992 and updated in 2014, limits the current THD for power systems of 69 kV and below to 5% or less. Why? Because high THD levels caused by the harmonics of non-sinusoidal power loads can wreak havoc on electrical systems if not controlled. For example, problems can include elevated RMS currents, nuisance fuse blowing, overheated transformer and distribution equipment, random tripping of breakers, equipment malfunctions, and shorter life spans for motors and other expensive components.

To explain, VFDs by their nature introduce non-linear loads into the electrical systems to which they're connected. These create harmonic distortions that draw non-sinusoidal current from the power source. At the input terminals of a typical VFD utilizing a 6-pulse rectifier, the THD of the current back to the source can be as high as 35%.

In order to lower THD, multi-pulse transformers placed on a VFD's line side are the most common solution. They use a 6-pulse bridge rectifier (Figure 1) as a common building block to help reduce the distorted non-sinusoidal currents as shown in Figure 2 below.

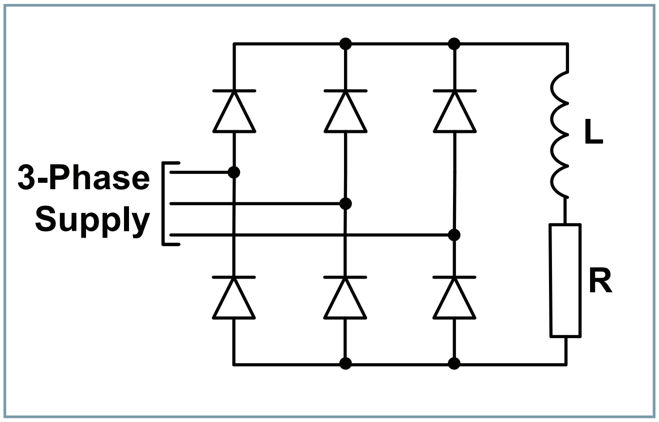

Figure 1. Six-pulse bridge rectifier

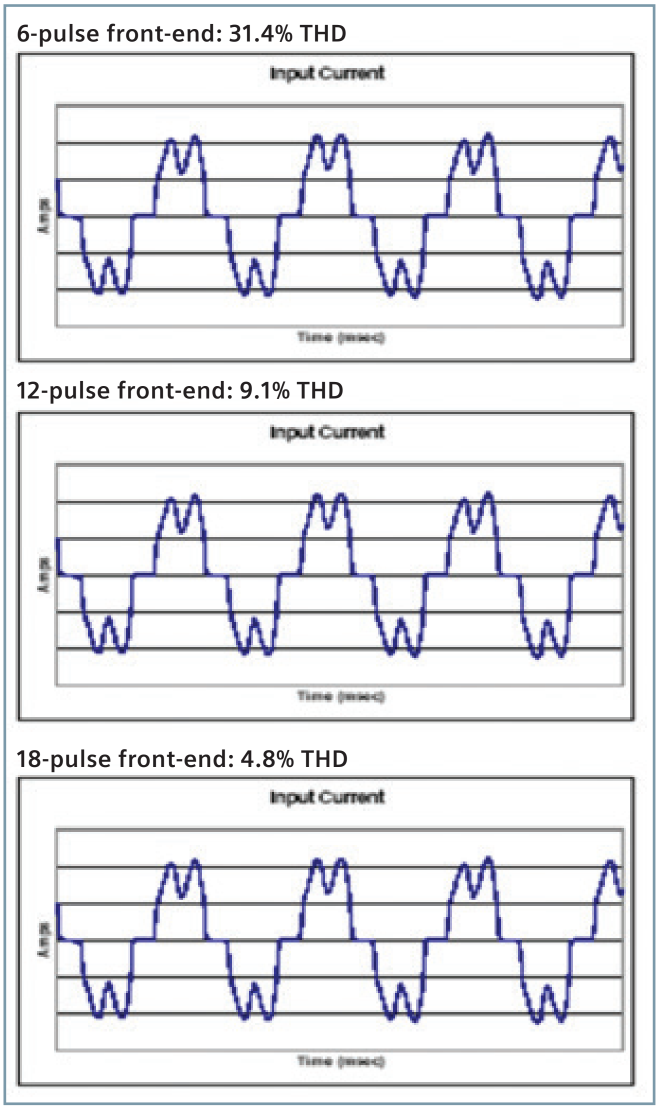

Figure 2. How progressive pulse front-ends can lower THD levels in VFD-connected electrical systems

An 18-pulse VFD lowers harmonic distortion with the phased cancellation of lower order harmonics that can cause resonance on capacitive and inductive loads, such as filters, transformers and other electrical components. Depending on the circuit impedance, an 18-pulse VFD can lower the current THD at the input terminals to less than 5%.

As shown in Figure 3, with an 18-pulse VFD input, the current THD of the current is 1.98% — well below the 5% limit set forth by IEEE-519.

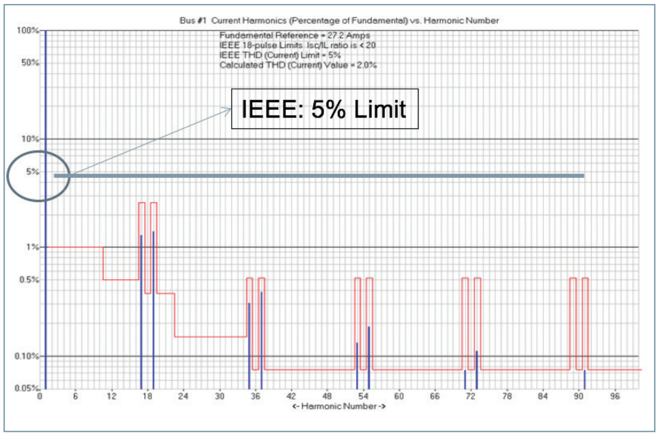

Figure 3. 18-pulse VFD input

By comparison, as shown in Figure 4, a 24-pulse VFD input, the current THD of the current is 1.14% — also well below the 5% limit set forth by IEEE-519, but just 0.84% less than what an 18-pulse VFD input provides.

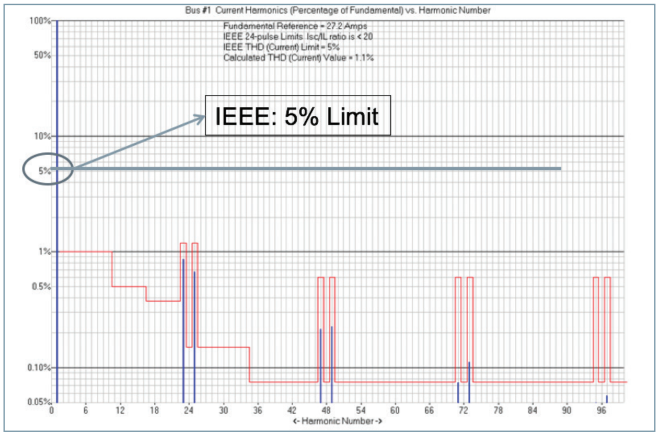

Figure 4. 24-pulse VFD input

When bigger isn't better: Higher costs and larger footprint with 24-pulse VFDs

Increasingly, RFP and RFQ specifications call for 24-pulse VFDs instead of specifying THD compliance less than the 5% upper limit set by IEEE 519. The distinction can cost operators a lot of money and require more space, while only buying them an extremely small decrease — 0.84% — in the THD of the overall electrical system.

What do plant operators get with that miniscule 0.84% improvement in THD from a 24-pulse VFD compared to an 18-pulse VFD? For starters, they don't get any more compliance with IEEE 519. As mentioned, an 18-pulse VFD lowers THD to 1.98%, less than half the 5% upper limit for THD, while 24-pulse VFD lowers THD just a bit more to 1.14%.

But to get that 0.84% improvement, 24-pulse VFDs can impose three big costs on operators:

- Larger VFD footprint (usually an additional 24-inch cabinet) and associated costs;
- Larger and more expensive transformer;
- Decrease in energy efficiency due to additional rectifier components and transformer secondary windings.

In fact, a 24-pulse VFD can require as much as 16% more in upfront capital costs due to the additional rectifier circuits and transformer windings needed.

What's more, 24-pulse VFDs are less energy efficient than 18-pulse VFD, due to the use of an additional 6-pulse rectifier, which adds 0.2% in energy losses to the system. That is why a 24-pulse VFD can cost a plant as much as $48,000 more in additional power costs over a typical 15-year operating life of a VFD, when compared to an 18-pulse VFD.

Those savings, as described in the sidebar, can help cover maintenance, spare parts or any other associated costs, lowering the machinery's total cost of ownership (TCO).

Conclusion: 18-pulse VFDs meet IEEE 519 THD limits yet save money and space

When it comes to meeting IEEE 519 specifications for limiting current THD to less than 5%, bigger isn't not better once the VFD solution has met that threshold. The fact is, both 18-pulse and 24-pulse VFD inputs provide harmonic performance well below the IEEE standard.

But while moving from an 18-pulse to a 24-pulse only improves the current THD by 0.84%, it also increases capital costs by 16% and boosts operating costs significantly over the life of the VFD. And that does not count the extra space that a 24-pulse VFD will typically require. In short, plant operators who buy 24-pulse VFD solutions are paying substantially more in both CAPEX and OPEX for an increase in harmonic mitigation that is essentially meaningless in practical terms.

At Siemens, we always seek to understand the true and practical requirements of our customers and meet those with the best, and most optimized solutions to provide the highest performance, greatest reliability, and lowest TCO over their entire lifecycles. The industry trend toward specifying 24-pulse VFD solutions despite their higher costs does not benefit plant operators but does help manufacturers that only make 24-pulse VFDs sell more of their products. We recommend that anyone considering a 24-pulse VFD solution think twice and evaluate if an 18-pulse VFD model to determine if the THD requirements can be met with less cost and space.

We invite you to contact Siemens for a complimentary, onsite evaluation of your requirements by one of our qualified engineers. Given the average 15-year lifecycle of your VFD solution, this extra step is a small investment in time that could have a big payoff right from the start and throughout the life of your VFD solution.

How less energy efficiency in a 24-pulse VFD can cost up to $48,000 more in operating expenses over its lifespan

- **Assume a 5000 hp (3730 kW) VFD operates 12 hours a day for between 260 and 365 days.**
- **Assume commercial power costs $0.10/ kW-hour, the U.S. average, per the U.S. Energy Information Administration.**
- **Adding an additional 6-pulse rectifier circuit (18-pulse to 24P) adds 0.2% energy losses.**
- **Over a typical 15-year operating life of a VFD system, the operating costs associated with 24-pulse VFD operation is between $35,100 and $48,000**
- **This costs delivers no significant improvement to plant operations.**

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