Drives, and the Black Cloud of Power Quality

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Black cloud? You may wonder if you read that right. What could possibly be dark or disturbing about power quality? Isn't power quality just the business of delivering clean power? Rest assured, power quality is important to all of us. We depend on our power provider to deliver a sinusoidal voltage source, so that we might plug in everything from radios to computers to industrial control equipment and have that gear operate correctly. But a segment of the market we call power quality unknowingly may have undermined the full potential of the business of drives.

At the heart of this phenomena is the 1992 printing of IEEE-519. Arguably -- and I'm sure there will arguments, post-haste -- IEEE-519, 1992 has its basis in the need for a clean voltage source. At the risk of oversimplifying a complex subject, consider this: IEEE drafted a recommendation in 1981 under which U.S. power providers would be obliged to provide a voltage source almost free of harmonic distortion. Total harmonic distortion of voltage was to be held to less than 5% of the value of the fundamental frequency. It was a sure bet that we would load our electrical grid with computers and control devices that would have varying, but low tolerance to distorted voltage, and therefore limiting distortion meant protecting equipment. You know the rest: When electricity utilities realized that they were being held to a standard and that load-demanded current distortion contributed to voltage distortion, the document was re-written. The 1992 revision incorporated recommended levels for current distortion, measurable at a point of common coupling (PCC). Overnight, the users of energy were equally responsible for power quality.

There were many reactions to IEEE-519-1992, and its major responsibility swing:

1. Power quality "gurus" - so-called specialists that blended math, magic and salesmanship - appeared everywhere. They arrived at industrial facilities with meters and probes and recommended special transformers and black boxes. They charged big consulting fees and gave seminar after seminar after seminar. They sold tons of hardware to reluctant but fearful power users.
2. Providers of solid state electronic equipment like drives began to see specifications that required that their equipment "meet IEEE-519". In fact, the recommendation as written does not include any equipment-specific distortion level. Drives that provided productivity improvements and energy efficiency gains came under heavy scrutiny. Arguments ensued and position papers were written. Specifiers and sellers pointed fingers; customers remained confused.

It may be that the U.S. AC drives market, with a starting value of $500 million and on pace to double in three years, was slowed by the hype surrounding power quality.

TRANS-COIL, INC.
7878 N. 86th Street
Milwaukee, Wisconsin 53224
Phone 414-357-4480 - Fax 414-357-4484 - 800-824-8282

www.transcoil.com

In addition, if the power quality equipment providers sold, say, $50 million in equipment, it might be safe to speculate that the drives market was slowed by that same dollar amount. With a starting value of $500 million, variable speed drives for motor control, which show an immediate pay back to the user and allow the utility to stretch its resources, were rejected in favor of assorted expensive facility filtering schemes and huge consulting fees, without any promise of pay back!

Hold on, you say. Aren't drives a significant contributor of harmonics? Shouldn't we worry that too many harmonics in a system might lead to shutdown, or a burning transformer, or failed power factor correction? Well that depends. Consider these two, very different applications:

I recently met a plant engineer for a dynamic, cutting-edge manufacturer of silicone wafers for use in computer chips. The purpose of our meeting was to discuss how he could gain the benefits of speed control on the dozens, if not hundreds of fans and pumps that deliver clean air to clean rooms where chips are grown, while control and computers receive pure sine wave voltage. I've heard more reasons for harmonic control than I care to admit, but this man finally made it all come together for me. He understood that those perfect sweeps of voltage had a direct correlation to his plant's output. Clean power in, he said, insured a high quality product with no downtime. He has chosen to incorporate12-pulse technology into his specification for all AC drives. The higher investment in 12-pulse technology will soon disappear as the plant churns out product and brings in profits. The equipment providers that bid for his work will face a challenging specification that extends the technical competence of both their gear and their application engineers. And the cost of chips will continue to go down as productivity is increased.

Maximum Harmonic Current Distortion in % if I_L						
Individual Harmonic Order (Odd Harmonics)						
I_{sc}/I_l	<11	11 £ h < 17	17 £ h <23	23 £ h < 35	35 £ h	TDD
<20*	4.0	2.0	1.5	0.6	0.3	5.0
20<50	7.0	3.5	2.5	1.0	0.5	8.0
50<100	10.0	4.5	4.0	1.5	0.7	12.0
100<1000	12.0	5.5	5.0	2.0	1.0	15.0
>1000	15.0	7.0	6.0	2.5	1.4	20.0
Even harmonics are limited to 25% of the odd harmonic limits. TDD refers to Total Demand Distortion and is based on the average maximum demand currect at the fundamental frequency, taken at the PCC.						
* All power generation equipment is limited to these values of current distortion regardless of I_{sc}/I_l						
I_{sc}/I_l = Maximum short circuit current at the PCC I_l = Maximum demand load current (fundamental) at the PCC h = Harmonic number						

Figure 1, from IEEE-519, 1992

I also know an engineer on the East Coast who designs commercial buildings. Architects and their Electrical and Mechanical Engineering specialists make sure that their customers receive high quality designs by maintaining and adhering to a state-of-the-art library of recommendations and standards. There is more than one engineer, this one included, who has read IEEE-519, and determined that the lowest levels listed in table 10.3 (See figure 1) must, in fact, be the safest standard to write into their specifications. Unfortunately, when this type of limit is mandated, most good intentions are lost and costs go up. Either a single niche-oriented provider can write his own ticket or competing hardware providers will have to charge much more for non-standard products. Cost increases created by these mandates are ultimately carried by the user. And if the job is Municipal the users are you and I. We pay the bill with tax dollars. I've seen manufacturers of drives scramble to deliver expensive alternative topologies, or feign misunderstanding of the intent of the specification, or walk away from the job altogether. Instead of receiving an energy efficient building on time, the user often must contend with construction delays and bickering before he receives the keys, and with a lingering bad taste about drives.

The difference between these two applications is clear. The first is a perfect example of purposeful engineering, with clear objectives for performance and cost. The second is an unfortunate misinterpretation of a well-intended recommendation.

There is a balance and it needn't be hard to achieve. Harmonic distortion control measures should be weighed mindful of hardware and installation costs, as well as the long-term benefits that harmonic control creates. In addition, the cost of the harmonic control devices or methods should be held to reasonable limits by smart engineering from the start of any project. Consider the following graphs. Figure 2 shows current and voltage distortion levels utilizing varying drive topologies or filter products, measured against the installed cost of the equipment, including the drive.

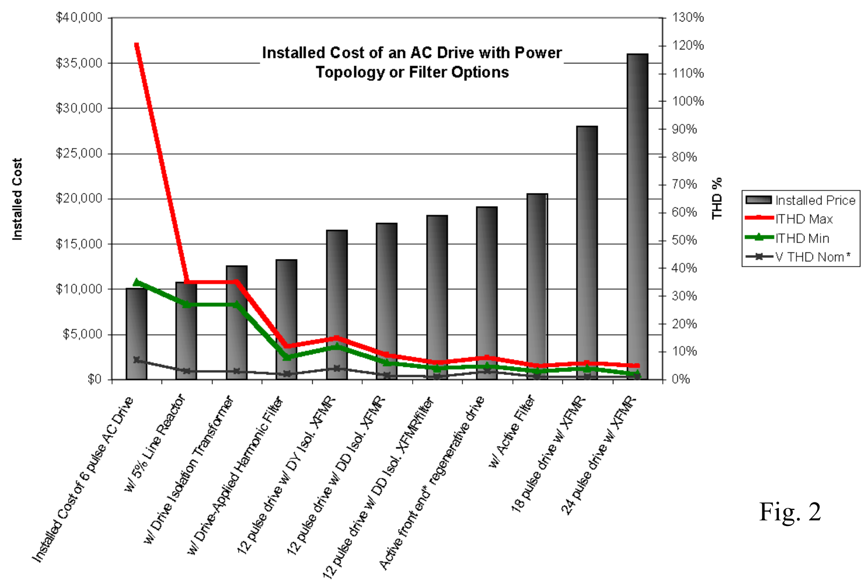

Fig. 2

Figure 3 summarizes the same information, and weighs the per-dollar cost of peripheral harmonic control equipment, or drive topology enhancements, versus performance. The lower the "performance factor" (a ratio of harmonic mitigation verses cost), the more cost effective the option. For instance: the current distortion performance factor for an AC drive with a drive-applied harmonic filter is 20. The same ratio for an 18-pulse drive is 39. Though the 18-pulse drive might have other performance or feature advantages not related to harmonic distortion control, it is nearly twice as expensive to control harmonics with an 18-pulse drive for the amount of mitigation realized.

Our friend at the wafer manufacturer went through a similar exercise before he made his choice.

Harmonic distortion mitigation or control should be considered in electrical environments that demand clean power and in facilities with significant content of non-linear load as a percentage of the total. (Sometimes these are one-in-the-same). Heavy industry, high-tech manufacturing, waste-water plants, commercial buildings with sensitive equipment, hospitals, laboratories, airport towers are all candidates for distortion control measures. Many choices for control are available. Remember the original intent of IEEE-519. It was meant to limit voltage distortion. It was not meant to slow the positive potential of the use of AC drives. AC drives either improve productivity or save energy. They are not power quality "problems," as some have portrayed them to be. Competition and improvement have brought AC drive prices to levels that make the energy savings opportunities almost too good to believe and impossible to ignore. Taking advantage of the benefits that they bring should be a primary focus for anyone. I'm sure that those that rode the post IEEE-519-1992 power quality bandwagon never intended to damage the potential of drives. And all told, the hype surrounding it did create a demand for education

-- which leads, in this writer's view, to the best way of addressing this complex subject.

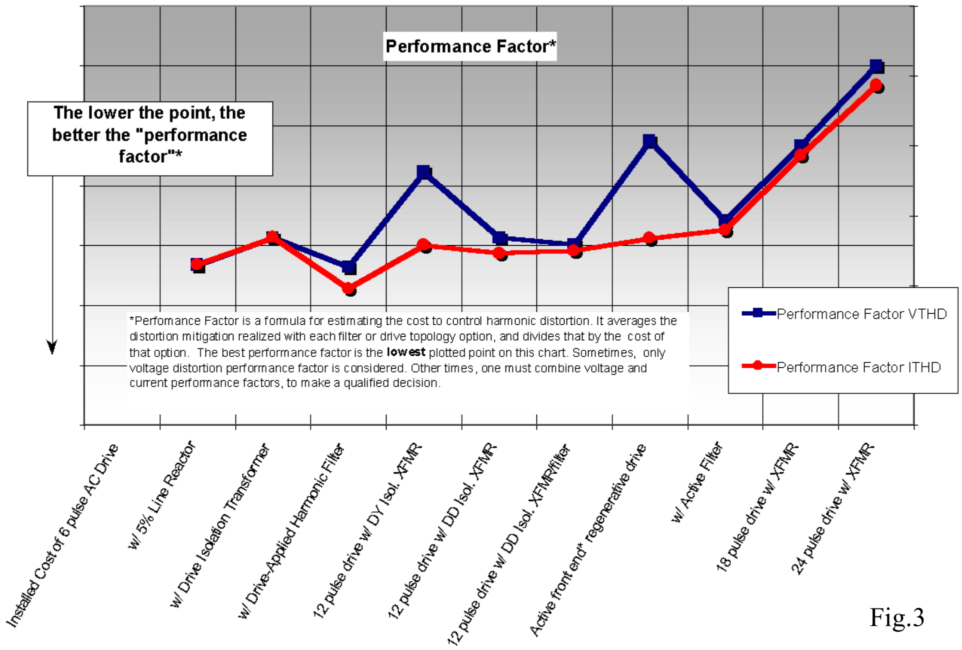

Fig.3

Education about harmonics as they relate to drives is critical. Harmonics in a three-phase electrical environment, where most drive exist, are very different in make-up and behavior than in a single phase electrical system. Take care in choosing a source for information about harmonics. Make certain that your teachers are qualified to discuss the various filter and drive topology options, and that they are not a providers of only one type of equipment. Also, listen carefully to what they say about drives. Again, drives are not a problem, they are a huge opportunity. The problem would be in not harnessing their potential. If your source seems more interested in scaring you with the horrors of harmonics, find another. And then find another, and another. Two sources are always better than one and five are better than two.

A host of educational options are available, including software, videos, white papers and seminars. This magazine often publishes information on the subject. I also recommend contacting companies like Fluke, BMI and testing or development organizations like PEAC or WEMPEC. Many have free or inexpensive classes or materials.

The black cloud of power quality that has shrouded drives has obscured benefits that drives could have afforded, all due to misconceptions about IEEE-519. Good buildings and systems are built by careful consideration of the customers' needs and by thorough justification of dollars spent. AC drives will continue to provide benefits that more than justify their costs, and power quality will be one of many factors to consider when applying them. Exceed your customers expectations by addressing both intelligently. Get educated!.

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