APPLICATION OF IEEE STD 519-1992 HARMONIC LIMITS

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Abstract: IEEE Std 519-1992 is a useful document for understanding harmonics and applying harmonic limits in power systems. Despite many years of good use there is still some confusion about how to apply certain aspects of the standard. This paper discusses some of those, as well as related issues that are helpful in working with harmonic limits.

There is considerable debate as to precisely how some elements of IEEE Std 519-1992 should be interpreted. This paper presents the authors' views on some of the more ambiguous elements of the standard and on the application of harmonic limits in general.

Key Words: Harmonics, harmonic limits, IEEE Std 519-1992, point of common coupling (PCC), total demand distortion (TDD).

I. Introduction

Harmonics are a concern because they can cause excessive heating and pulsating and reduced torque in motors and generators; increased heating and voltage stress in capacitors; and misoperation in electronics, switchgear and relaying. In short, harmonics can lead to reduced equipment life if a system is designed without consideration for harmonics and if equipment is not properly rated and applied.

It is therefore useful to measure and limit harmonics in electric power systems. IEEE Std 519-1992, *IEEE Recommended Practices and Requirements for Harmonic Control in Electric Power Systems* (IEEE 519) [1], provides a basis for limiting harmonics. This document does an excellent job of defining the limits but there are some application issues that require the reader to use his or her judgment.

One very basic distinction when discussing harmonics is whether the harmonics in question are voltage harmonics or current harmonics. It is the authors' experience that many people do not clarify this when discussing harmonics. For example, people will talk about total harmonic distortion, in percent, without specifying voltage or current.

Generally speaking, power systems have low source impedance and well-regulated voltage. They can tolerate significant disruptions outside of steady 60 Hz loading, including harmonic currents, without causing significant voltage distortion. For a given amount of harmonic current flow, the resulting voltage distortion will be relatively small (excepting harmonic resonance situations). Therefore, when someone mentions harmonic levels well in excess of 5% he is probably talking about current harmonics.

Harmonics add in a root-sum-square (square root of the sum of the squares of different frequency components) fashion. This means that 100 A of 60 Hz current combined with 20 A of 5th harmonic current (300 Hz) adds up to 102 A_{RMS}, not 120 A. Unless harmonics are very high, the RMS current is likely to be very close to the 60 Hz fundamental current. This is especially true for voltages because the voltage harmonic distortion is almost always less than the current distortion.

It is useful to talk about harmonics in terms of percent of fundamental to get an understanding of the relative harmonic levels in a system. When working with the limits discussed in this paper and when performing harmonic analysis studies, however, it is generally more useful to receive harmonic information in actual quantities, volts or amperes at different frequencies.

II. Harmonic Limits

A. Voltage and Current Harmonic Limits

According to IEEE 519, harmonic voltage distortion on power systems 69 kV and below is limited to 5.0% total harmonic distortion (THD) with each individual harmonic limited to 3%. The current harmonic limits vary based on the short circuit strength of the system they are being injected into. Essentially, the more the system is able to handle harmonic currents, the more the customer is allowed to inject.

Table 1. *IEEE Std 519-1992 Harmonic Voltage Limits*

Voltage Distortion Limits

Bus Voltage at PCC	Individual Voltage Distortion (%)	Total Voltage Distortion THD (%)
69 kV and below	3.0	5.0
69.001 kV through 161 kV	1.5	2.5
161.001 kV and above	1.0	1.5
NOTE: High-voltage systems can have up to 2.0% THD where the cause is an HVDC terminal that will attenuate by the time it is tapped for a user.		

Table 2. *IEEE Std 519-1992 Harmonic Current Limits*

Current Distortion Limits for General Distribution Systems (120 V Through 69000 V)

Maximum Harmonic Current Distortion in Percent of I_L						
Individual Harmonic Order (Odd Harmonics)						
I_{SC}/I_L	<11	$11 \leq h < 17$	$17 \leq h < 23$	$23 \leq h < 35$	$35 \leq h$	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 above.						
Current distortions that result in a dc offset, e.g. half-wave converters, are not allowed.						
* All power generation equipment is limited to these values of current distortion, regardless of actual I_{sc}/I_L.						

Where

- I_{sc} = maximum short-circuit current at PCC.
- I_L = maximum demand load current (fundamental frequency component) at PCC.
- TDD = Total demand distortion (RSS), harmonic current distortion in % of maximum demand load current (15 or 30 min demand).
- PCC = Point of common coupling.

Table 1 shows the IEEE 519 harmonic voltage limits while Table 2 shows the harmonic current limits.

The harmonic current limits specify the maximum amount of harmonic current that the customer can inject into the utility system. The utility is responsible for providing a clean (low distortion) voltage to the customer. The utility can only be fairly judged, however, when the customer meets the harmonic current limits. Otherwise, the customer may be guilty of causing the voltage distortion himself. The intent of IEEE 519 is stated in its Forward:

> This recommended practice recognizes the responsibility that users have not to degrade the voltage of the utility serving other users by requiring nonlinear currents from the utility. It also recognizes the responsibility of the utilities to provide users with close to a sine wave of voltage.

Section 10.2 of IEEE 519 goes on to say:

> The philosophy of developing harmonic limits in this recommended practice is to

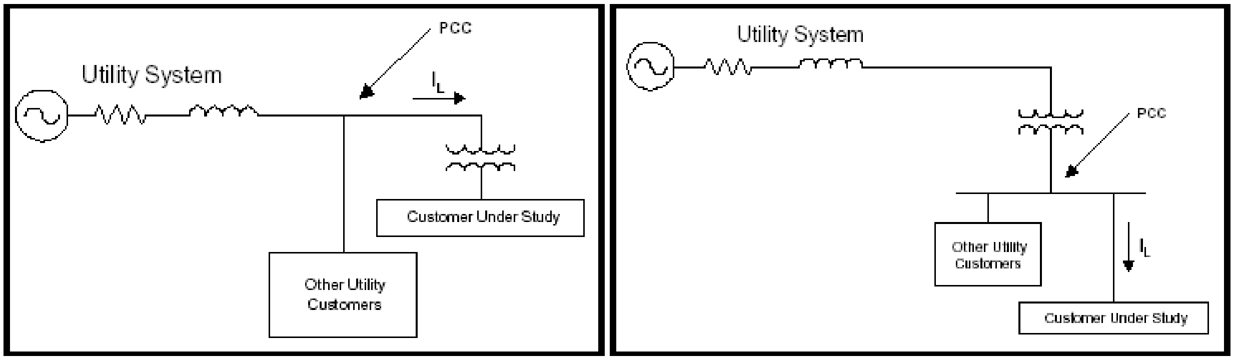

Figure 1. *Point of Common Coupling*
From IEEE 519A Applications Guide (Draft)

1) Limit the harmonic injection from individual customers so that they will not cause unacceptable voltage distortion levels for normal system characteristics
2) Limit the overall harmonic distortion of the system voltage supplied by the utility

These limits are intended to be applied at the point of common coupling (PCC) between the customer and the utility. Within the customer's facility these limits do not apply but they are still useful guides for judging harmonic levels within the customer's facility.

Issues associated with the application of these limits comprise the rest of this paper.

III. Point of Common Coupling (PCC)

A. Definition

The PCC is one of the most misunderstood parts of IEEE 519. The IEEE working group [2] that is revising IEEE 519 has clarified the definition of the PCC as follows:

> The Point of Common Coupling (PCC) with the consumer/utility interface is the closest point on the utility side of the customer's service where another utility customer is or could be supplied. The ownership of any apparatus such as a transformer that the utility might provide in the customers system is immaterial to the definition of the PCC. Note: This definition has been approved by the 519 Working Group.

This clarification is necessary because Section 10.1 of the present IEEE 519 states:

> The recommendation described in this document attempts to reduce the harmonic effects at any point in the entire system by establishing limits on certain harmonic indices (currents and voltages) at the point of common coupling (PCC), a point of metering, or any point as long as both the utility and the consumer can either access the point for direct measurement of the harmonic indices meaningful to both or can estimate the harmonic indices at point of interference (POI) through mutually agreeable methods. Within an industrial plant, the PCC is the point between the nonlinear load and other loads.

This paragraph allows one to assess the harmonic limits practically anywhere. There is nothing wrong with that as long as both parties agree. But it does not square with the intent of the standard as given in the Forward (quoted earlier).

Based on the quote from Section 10.1 of IEEE 519, some people prefer to define the PCC (or multiple PCCs) at a point (or points) internal to the customer's system. This implies that harmonic limits must be met internally, in the customer's system. Many consultants, for example, use this statement to try to force manufacturers of non-linear loads (drives, rectifiers, etc.) to adhere to the IEEE 519 limits for a single load. This can result in significant costs for end users and was never the intent of the standard.

The goal of applying the harmonic limits specified in IEEE 519 is to prevent one customer from causing harmonic problems for another customer or for the utility. If you have high harmonics within your own system you are only hurting yourself, but not necessarily violating IEEE 519.

Certainly it might be a very good idea to voluntarily limit harmonics within your own system in order to avoid operational problems, perhaps to the levels specified in IEEE 519, but IEEE 519 only applies to the point where you can affect your neighbor, the PCC. Only if you have multiple feeds from the utility would you have multiple PCCs. The PCC is the only point where you must meet the IEEE 519 limits, if IEEE 519 is incorporated into the contract or applicable rate (IEEE 519 is a *Recommended Practice*).

B. PCC Application Advice

In practice this means that the true PCC will most often be at the medium voltage primary of the transformer serving the customer, regardless of transformer ownership or metering location. In the real world, of course, it is often only practical to perform measurements on the transformer secondary. System modeling would be required to calculate the resulting voltage distortion on the transformer primary, although the current percentages would transform straight through. Use the I_{sc}/I_L ratio on the transformer primary when deciding which row of limits apply. In the majority of cases, all but the balanced triplen harmonic currents will appear on both sides of the transformer simply scaled by the transformer ratio.

The vast majority of the time measurements on the transformer secondary are sufficient to determine whether there is a harmonics problem so it is not necessary to use the precise PCC definition. But we should keep in mind that we are simply doing what we can out of convenience, not what we would do in a perfect world where we could measure anywhere safely and easily. If there is a dispute between a utility and a customer about IEEE 519 harmonic levels, it may then be necessary to measure and/or calculate harmonics at the true PCC.

IV. I_{SC}/I_L Ratio

As shown in Table 2 and mentioned briefly earlier in this paper, the harmonic limits that apply to a particular customer depend on the I_{SC}/I_L ratio at that customer's point of common coupling with the utility. As defined in IEEE 519, I_{SC} is the "maximum short-circuit current at PCC." This should be a three-phase bolted fault current. I_L is the "maximum demand load current (fundamental frequency component) at PCC." This is a current calculated from the maximum billing (e.g. 15 or 30 minute) demand, not an instantaneous peak—a very important distinction.

This ratio shows the relative impact that a given customer can have on the utility. A customer with a small demand relative to the short circuit current available cannot cause much disruption to the utility system. Thus such a customer is allowed higher harmonic current limits. Conversely, a large customer (high I_L) relative to the available fault current faces stricter limits.

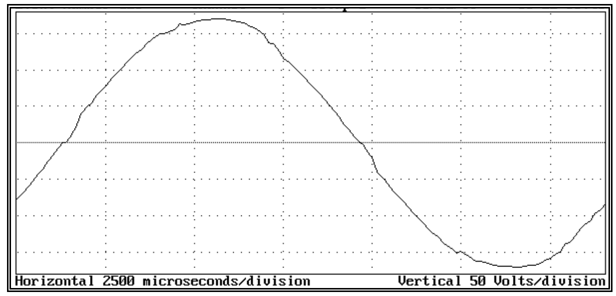

Figure 2. *Load Served by Utility Source Voltage Distortion (THD_V) = 2.3%*

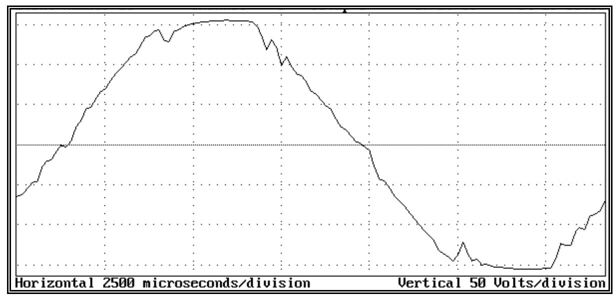

Figure 3. *Load Served by Backup Generator Voltage Distortion (THD_V) = 5.7%*

Without knowing specific information about a utility's system (I_{sc}, in order to calculate the I_{sc}/I_L ratio) the row of harmonic current limits that applies cannot be determined.

Sometimes the utility provides the three-phase short circuit MVA (MVA_{SC}). In this case it may be more convenient to calculate the MVA_{SC}/MVA_L ratio. This value is the same as the I_{sc}/I_L ratio.

In actual power systems the short circuit current can vary depending on system configuration and utility generators in service. For the purposes of determining which harmonic limits apply the maximum short circuit current is used, just as in a short circuit study. When performing harmonic analysis studies, however, it is often better to use a lower estimate of available short circuit current in order to obtain a more conservative result (higher calculated harmonic voltage distortion).

There are situations that can significantly change the I_{sc}/I_L ratio. One common situation is operating under backup generator power, where the I_{sc}/I_L ratio would be much lower than during utility operation. The IEEE 519 limits would not strictly apply because there is no interconnection with the utility and other customers. Even so IEEE 519 would still provide guidance on how the harmonic currents should be limited within the customer's system to avoid harmonic problems.

Figures 2 and 3 show the same load when served by utility power and by a backup generator. Notice the significant increase in voltage distortion when served by the generator, which is typically a much weaker (lower short circuit current) source than the utility.

V. Total Demand Distortion

A. Definition

Another misunderstood part of the IEEE 519 standard is the term *total demand distortion*, or *TDD*. From Table 2, above, "Total demand distortion (RSS), harmonic current distortion in % of maximum demand load current (15 or 30 min demand)." (RSS is the *root-sum-square*, or square root of the sum of individual harmonic components squared.) The term *TDD* is very much like the *total harmonic distortion*, or *THD*. In these examples, THD and TDD are calculated in terms of current.

$$THD_I = \frac{\sqrt{I_2^2 + I_3^2 + I_4^2 + I_5^2 + \ldots}}{I_1}$$

$$TDD_I = \frac{\sqrt{I_2^2 + I_3^2 + I_4^2 + I_5^2 + \ldots}}{I_L}$$

I_1, I_2, I_3, et cetera are harmonic currents, in amperes. I_1 refers to the fundamental frequency current, most commonly 60 Hz in North America. I_2 refers to the second harmonic, or the current at twice the fundamental frequency (120 Hz, if the fundamental is 60 Hz). And so on.

I_L is defined as the "maximum demand load current (fundamental frequency component) at PCC." This would be the maximum current averaged over a demand interval (e.g. 15 or 30 minutes) for a given customer.

The two definitions are very much alike. The only difference is the denominator. The THD calculation compares the measured harmonics with the measured fundamental current. The TDD calculation compares the measured harmonics with the maximum demand current.

Similarly, the individual harmonic current limits are not given in terms of percent of fundamental (as is typical of most harmonic measurements) at a given point of time. The current limits are given in terms of, "Maximum Harmonic Current Distortion in Percent of I_L."

Note that commercially available instruments measure THD and individual harmonics in percent of I_1.

I_L will almost always be greater than I_1 for harmonic measurement purposes. I_1 may momentarily exceed I_L but if so higher harmonic limits would apply. IEEE 519 states that the harmonic current limits "should be used as system design values for the 'worst case' for normal operation (conditions lasting longer than one hour). For shorter periods, during start-ups or unusual conditions, the limits may be exceeded by 50%." [1] If there is a condition lasting longer than an hour, then a new I_L has also been reached. Therefore the TDD and percent of I_L measurements will almost always be less than the THD and percent of I_1 measurements.

In a new installation (or proposed load addition) the demand current (or increase in demand current) may not be not known. This leads to some difficulty when estimating harmonics. Without knowing what the actual demand current will be once a facility is operational it is not possible to know with certainty which row of harmonic current limits apply. Therefore, the engineer should strive for an accurate estimate of the maximum demand current. If this is not possible, the transformer full load current is sometimes used to approximate the maximum demand current.

The difference between THD and TDD (and between harmonics as a percent of I_1 and I_L) is important because it prevents a user from being unfairly penalized for harmonics during periods of light load. During periods of light load it can appear that harmonic levels have increased in terms of percent even though the actual harmonic currents in amperes have stayed the same or decreased. Let us look at a numerical example to illustrate this difference.

B. Assumptions for Example Calculations

Our example plant has two distinct manufacturing areas, one with some harmonic load and another with only linear load. The portion of the plant with the harmonic load draws 1000 A at 60 Hz (I_1), 140 A at 300 Hz (I_5), and 70 A at 420 Hz (I_7). The portion of the plant with only linear load draws 1000 A at 60 Hz (I_1). See Figure 4 for a simple sketch of the example power system.

Let us assume that these currents are on the secondary of a 12470-480 V transformer. The PCC is on the primary of the transformer, and the three-phase short circuit MVA (MVA_{SC}) on the primary is 50 MVA (information provided by the utility). It is often more convenient to determine the I_{SC}/I_L ratio by calculating the MVA_{SC}/MVA_L ratio. The two ratios are the same and determining the MVA ratio is often a bit easier. In this case the load MVA is 1.66, yielding a MVA_{SC}/MVA_L ratio of 30.1. This means that the second row of harmonic current limits apply (limiting TDD to 8% and individual harmonics below the 11^{th} to 7% or less).

Let us also assume that currents at the same frequency may be simply added (no cancellation due to phase angle/power factor differences).

C. Example 1: Plant at Full Load

With both portions of the plant running we would have a total of 2000 A at 60 Hz (I_1), 140 A at 300 Hz (I_5), and 70 A at 420 Hz (I_7). Assuming this is the plant's maximum load (averaged over the demand interval), we would calculate the demand current, I_L, to be 2000 A (maximum demand, fundamental frequency component)

This would result in the following calculations:

$$THD_I = \frac{\sqrt{I_5^2 + I_7^2}}{I_1} = \frac{\sqrt{140^2 + 70^2}}{2000} = 7.83\%$$

$$TDD_I = \frac{\sqrt{I_5^2 + I_7^2}}{I_L} = \frac{\sqrt{140^2 + 70^2}}{2000} = 7.83\%$$

I_5 as a percent of I_1 would be 140/2000, or 7.0%. I_5 as a percent of I_L would also be 140/2000, or 7.0%.

In this case, the harmonic current limits for both TDD and individual harmonics as a percent of I_L are barely met. The limits would also be met if we were using THD and individual harmonics as a percent of I_1. The latter are what harmonic measurement instruments commonly report.

D. Example 2: Plant at Partial Load

In this case, only the harmonic portion of the plant is running. We therefore only have 1000 A at 60 Hz. However, the demand current, I_L, previously calculated does not change.

This would result in the following calculations:

$$THD_I = \frac{\sqrt{I_5^2 + I_7^2}}{I_1} = \frac{\sqrt{140^2 + 70^2}}{1000} = 15.65\%$$

$$TDD_I = \frac{\sqrt{I_5^2 + I_7^2}}{I_L} = \frac{\sqrt{140^2 + 70^2}}{2000} = 7.83\%$$

I_5 as a percent of I_1 would be 140/1000, or 14.0%. I_5 as a percent of I_L would be 140/2000, or 7.0%.

In this case, the harmonic current limits for both TDD and individual harmonics as a percent of I_L are barely met. However, the limits would not be met if we were using THD and individual harmonics as a percent of I_1.

The numbers as a percent of I_1, rather than I_L, can go up rather dramatically depending on which loads within a plant are on at any given time. But

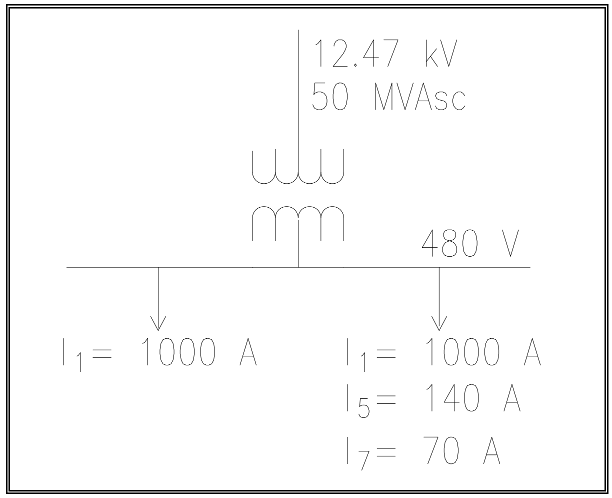

Figure 4. *Example Power System with Linear and Harmonic Loads*

the plant should not be penalized in this case because it is not injecting any more harmonic current into the utility system in Measurement 2 than it is during Measurement 1.

E. TDD Application Advice

All of the above means that there is a certain amount of post-processing of harmonic measurement data that is necessary to properly assess compliance with IEEE 519 current limits. This means that in most cases when we compare measured harmonic current data (THD, not TDD; individual harmonics in percent of I_1, not in percent of I_L) to IEEE 519 limits we are not doing an apples-to-apples comparison.

To ensure that we have valid harmonic measurements we want to make sure that all harmonic loads are operating normally during the measurements, of course. In addition to that, to ensure that the THD measurements (and all individual harmonic measurements calculated as a percent of I_1) closely match the TDD measurements (and all individual harmonic measurements calculated as a percent of I_L) we also want to make sure that our measurements are taken at a time when all of the linear loads are operating normally.

As with the PCC discussion, there is what you would want to do in a perfect world and what you can actually do in the real world. In the real world we do not often need to convert the THD and percent of I_1 measurements to TDD and percent of I_L measurements. The majority of the time, the THD and percent of I_1 measurements are sufficient. If the THD and percent of I_1 measurements meet the IEEE 519 limits then the TDD and percent of I_L measurements will, by definition, also meet the limits (since I_L is greater than I_1, the TDD and

Table 3. *18-Pulse Clean Power Drive Current Measurements, Various Speeds*
(All Values in Amperes Except as Specified in Percent, Nominal I_L = 225 A)

HARMONIC	30 Hz	40 Hz	50 Hz	60 Hz
THD (% of I_1)	26.7 %	14.1 %	9.1 %	5.9 %
TDD (% of I_L)	3.6 %	4.1 %	4.5 %	4.8 %
All Harmonics	8.2	9.2	10.1	10.8
RMS	31.9	65.8	110.7	183.1
1 (fundamental)	30.8	65.2	110.3	182.3
2	0.1	0.4	1.2	0.9
3	3.1	3.8	3.9	3.9
5	5.4	6.1	6.8	8.3
7	5.1	5.1	4.9	4.3
11	0.2	0.2	0.5	1.2
13	0.4	0.8	1.0	1.2
17	1.5	2.0	2.1	2.1
19	0.8	1.7	2.5	2.5
23	0.3	0.4	0.4	0.3
25	0.3	0.4	0.7	0.7
29	0.0	0.1	0.1	0.3
31	0.2	0.1	0.2	0.3
35	0.1	0.2	0.3	0.4
37	0.2	0.3	0.4	0.5

percent of I_L measurements will always be less than or equal to the THD and percent of I_1 measurements). If the limits are greatly exceeded when the measurements are taken at or near full load, then there is also no need to convert to TDD. If the numbers are close, you probably want to err on the side of caution and reduce the harmonics anyway.

Like the PCC, we should keep in mind that we are simply doing what we can out of convenience (THD, percent of I_1), not what we would do in a perfect world (TDD, percent of I_L) if we had the time to do post processing of measurement data. If there is a dispute between a utility and a customer, it may then be necessary to do the post processing required for an apples-to-apples comparison with the IEEE 519 harmonic current limits.

F. Amperes Versus Percent—Drive Example

Discussing harmonics in terms of percent of fundamental is useful to understand relative harmonic levels. When doing harmonic measurements, studies, and limit assessments it is more useful to talk in terms of actual quantities: volts and amperes at each harmonic frequency of interest.

One example that illustrates this difference is the operation of a variable frequency drive (VFD). VFDs produce current harmonics due to the way they draw current from the source. Common six-pulse drives produce 5^{th}, 7^{th}, 11^{th}, 13^{th}, 17^{th}, 19^{th} harmonics, and so forth. 12-pulse and 18-pulse drives incorporate designs that largely cancel certain lower order characteristic harmonics.

Some consultants, when they write a harmonic specification for an installation with drives, require verification measurements to ensure that the drives are working as expected. They also require that these measurements cover a variety of operating parameters, including varying the drive load. In the case of a pumping station, reducing the load means reducing the output frequency of the drive. The thinking behind this is that as the drive load decreases, the harmonics increase.

Table 3 shows measurements on an 18-pulse drive during such a verification measurement. The drive was operated at various output frequencies and the harmonics were measured. We are not comparing these measurements with any harmonic limits because this drive is just one part of a larger system. These measurements are presented to show how the drive harmonics vary with drive output frequency.

The data show that while the 60 Hz source current goes down significantly with output frequency the harmonic currents are not reduced that much. This makes it appear as though the drives are injecting more harmonics if one only looks at the harmonics as a percentage of 60 Hz current (THD, rather than TDD). Harmonics, in amperes, actually decrease as the output frequency is reduced, but one would not know that by only looking at the THD or individual harmonics that are calculated as a percent of decreasing fundamental current (I_1).

This is why the harmonic current limits are written in terms of percent of full load current, I_L (TDD), not percent of momentary fundamental current, I_1 (THD). Setting limits as a percent of fundamental would mean that the harmonic limits get more strict at periods of light load, even though less harmonic current is being injected.

These limits also show that, in general, full load drive operation is the worst case condition to analyze in harmonic studies and measurements. Studies and measurements at partial load are usually not worth the effort.

VI. Harmonic Limit Enforcement

As a practical matter, utilities do not often rigorously investigate or enforce the current limits unless problems are occurring somewhere in the distribution system. It is common to perform measurements at a facility with harmonic-producing loads and find harmonic current levels that are technically in excess of IEEE 519 current limits, without seeing any operational problems.

If problems are occurring, they will usually show up in excessive voltage distortion. It is possible to have one or several customers exceed IEEE 519 current limits without causing system problems if the utility system is lightly loaded or if there are a number of other customers that are below their harmonic current injection limits.

Sometimes harmonic problems seem to begin when a new customer connects to a utility system and this customer gets blamed for all the harmonic problems. In truth, that new customer is often not the source of all the problems, just the “straw that broke the camel’s back” and pushed the existing harmonic levels just a bit higher. Even though the problems seemed to start when that customer came on-line, the blame lies with all the harmonic-producing customers on the system.

System changes, whether on the utility system or within a customer’s facility, can also cause harmonic levels to rise. For example, the addition of power factor correction capacitors can change the harmonic resonance point of a power system and amplify injected harmonic currents, resulting in excessive voltage distortion. A discussion of this topic is beyond the scope of this paper.

VII. Conclusion

It is useful to measure and limit harmonics in electric power systems in order to avoid operational problems and equipment deterioration. IEEE Std 519-1992 defines harmonic limits, but there is some confusion as to how these limits are to be applied. Care should be taken to specify whether the harmonics in question are voltage or current harmonics and whether they are in actual quantities (volts or amperes) or in percent, in which case it should be further specified whether they are in percent of I_1 (most common) or I_L (as during a rigorous limits assessment).

The general intent of IEEE 519 is to limit harmonic current from individual customers and to limit distortion of the system voltage provided by utilities. Customers should not cause excessive harmonic currents to flow and utilities should provide a nearly sinusoidal voltage. The I_{SC}/I_L ratio must be known in order to determine which row of harmonic current limits apply.

One point of confusion in IEEE 519 is the Point of Common Coupling, or PCC. The PCC is the point where another customer can be served, regardless of metering location or equipment (transformer) ownership. The goal of applying the harmonic limits specified in IEEE 519 is to prevent one customer from causing harmonic problems for another customer or for the utility. The IEEE 519 limits may still be used as a guide within a customer’s facility to minimize harmonic problems.

Another point of confusion in IEEE 519 is the distinction between *total demand distortion* (TDD) and *total harmonic distortion* (THD). The difference between the two is that TDD expresses harmonics as a percent of maximum demand load current (I_L) and THD expresses harmonics as a percent of fundamental (60 Hz) current (I_1) at the time of the measurement. Individual harmonic currents should also be expressed as a percent of I_L before being compared to the harmonic limits in IEEE 519.

The difference between THD and TDD (and between harmonics as a percent of I_1 and I_L) is important because it prevents a user from being unfairly penalized for harmonics during periods of light load. Some loads, such as drives, have higher THD at light load, even though they are drawing less total harmonic current in amperes and thus causing less harmonic voltage distortion.

It is not always practical or necessary to either measure at the true PCC or convert THD values to TDD. Knowing how the IEEE 519 limits should be assessed, when possible, allows an engineer to determine whether his or her approach is good enough for the job at hand.

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Daniel J. Carnovale, P.E. is the Power Quality Solutions Manager at Eaton Electrical. Dan is responsible for developing strategies and tools for reliability and productivity solutions across the Electrical Group's 8 equipment divisions and Engineering Services group. Dan has developed and teaches CEU certified, technical seminars on Power Systems and Power System Analysis. He has conducted several hundred Power Quality site investigations for commercial, industrial and utility power systems: evaluating PQ issues and applying solutions. Dan worked for Westinghouse Engineering Services and ABB Power T&D. He received his B.S. Degree in Electrical Engineering from Gannon University and his M.S. Degree in Power Systems from Rensselaer Polytechnic University. He is a registered Professional Engineer in the states of Pennsylvania, California and Alaska.