Technical Note 158

IEEE 519-2022 Review

What has changed from the previous 2014 version?

This application note is a review of changes to the IEEE 519-2014 standard for the control of harmonic distortion in electric power systems. It is based on the Redline version of IEEE 519-2022 that was approved by the IEEE SA Standards Board on May 13, 2022 which shows the actual revisions to the 2022 version compared to the previously released 2014 version.

The following items are a listing of key changes or additions with *added comments* on what it may mean for those using, specifying, and designing equipment for electrical systems containing non-linear loads.

1. The **Title** has been changed from, *"IEEE Recommended Practice and Requirements for Harmonic Control in Electric Power Systems"* to *"IEEE Standard for Harmonic Control in Electric Power Systems"*.

   This is significant because past versions have historically designated this work as recommendations for limits on harmonic distortion, but it is now being treated as a standard. It is interesting to note, however, that even with the change to naming this as a standard, section 1.2 has the following statements that offer the flexibility that would be had by thinking of it as a recommendation.

   > **"This standard is to be used for guidance in the design of power systems with nonlinear loads. The limits set are for steady state operating conditions. In any case, the limit values given in this document should not be considered binding in all cases. Some conservatism is present that may not be necessary in all cases."**

2. Added in **1.1 Scope:**

   > **"The voltage and current distortion limits in this standard shall apply at the user point of common coupling (PCC) to overall installation containing harmonic producing loads (nonlinear equipment). Users are directed to other applicable standards such as IEEE Std 1547™ or IEEE Std 2800™ for current distortion limits of inverter-based resources (IBR) installations. When no other applicable standard exists, users shall continue to use footnote "c" under Table 2 through Table 4 in this standard for IBR connected to transmission systems. If an installation has a mix of harmonic producing loads and IBR at the same facility, users are directed to use Figure 1 in this document to determine whether IEEE 519 limits apply at the PCC."**

   Also added a paragraph and a decision tree in Figure 1 in **5.2 Current distortion limits**:

   > **"The current distortion limits shall apply to a user's PCC primarily with harmonic producing loads. For installations with primarily inverter-based resources, users are directed to other applicable standards such as IEEE Std 1547-2018 or IEEE Std 2800-2022. For installations where there is a mix of both loads and inverter- based resources, the decision tree in Figure 1 shows when IEEE Std 519 limits shall apply at the installation PCC."**

These additions are directing users to other standards for sites with power generating equipment used under the condition that the site is using electronic inverters or generators to supply power to the grid (for example, AFE rectifiers with photo-voltaic power sources, or regenerative drives with motors powered by water turbines on small dams, or battery storage systems that use AFE rectifiers to convert power from DC to AC to put power back onto the power grid) or other converters that may generate more than 10% of the facility's annual average load demand.

There are also some applications where the other standard(s) would apply instead of IEEE519.

From IEEE 1547-2018

"distributed energy resource (DER): A source of electric power that is not directly connected to a bulk power system. DER includes both generators and energy storage technologies capable of exporting active power to an EPS. An interconnection system or a supplemental DER device that is necessary for compliance with this standard is part of a DER."

From IEEE 2800-2022

"inverter-based resource (IBR): Any source of electric power that is connected to the transmission system (TS) via power electronic interface, and that consists of one or more IBR unit(s) capable of exporting active power from a primary energy source or energy storage system to a TS. A collector system or a supplemental IBR device that is necessary for compliance with this standard is part of an IBR."

3. Added in **1.1 Scope**:

   "The limits given in this document are based on assumptions that are technically justifiable at the PCC between the system owner/operator and user. These assumptions, and therefore the limits in this document, are not necessarily valid at any other point in the power system. For this reason, the limits given in this document are not intended to be used for the evaluation of equipment."

   This text is stating the intention that the limits are based on a measurement or estimation at the PCC and not at other points in the system or for the evaluation of individual pieces of equipment. It is important to note that even though a certain mix of drives can be shown to meet the limits in this IEEE 519-2022 standard at the PCC, harmonic issues may still occur. For example, voltage distortions of 8% can be a problem for some users even though they meet IEEE 519. For this reason, it may be better to work to achieve a lower voltage THD limit such as the limits found in the IEEE 519-1992 standard, Table 10.2.

4. Noted in **1.2 Purpose**:

   "The limits in this standard are intended for application at a PCC between the system owner or operator and a user, where the PCC is usually taken as the point in the power system closest to the user where the system owner or operator could offer service to another user. Frequently for service to industrial users (i.e., manufacturing plants) via a dedicated service transformer, the PCC is at the HV side of the transformer. For commercial users (office parks, shopping malls, etc.) supplied through a common service transformer, the PCC is commonly at the LV side of the service transformer."

   Details of where the limits would normally be examined are given in this note for different types of users depending on the normal placement of the PCC.

5. Added in **1.3 Word usage**:

   Definitions on the usage of shall, should, may and can are explained in a way that is found in other standards.

   This addition helps the user to understand the intention of the text based on certain word meanings. For example, ***Shall*** *equals* ***is required to****, while* ***Should*** *equals* ***is recommend that,*** *while* ***May*** *equals* ***is permitted to*** *and* ***Can*** *equals* ***is able to****.*

6. Changed in **2. Normative references**:

   Other standards were added or removed giving a list of standards that are useful in dealing with harmonics in power systems.

7. Key changes in **3.1 Definitions**:

maximum demand load current: This current value is established at the point of common coupling and shall ~~should~~ be taken as the sum of the rms currents corresponding to the 15 min or 30 min maximum demand during each of the twelve previous months divided by 12. If 12 months of data is not available due to the length of time in service, then the maximum 15 min or 30 min apparent power demand for each month should be summed over the total number of months available, and then divided by the number of months. For situations where the installation is a proposed new installation, the maximum demand load current shall be based on the projected 15 min or 30 min maximum monthly apparent power demand over the course of the year following operation of the proposed harmonic producing loads listed on the service application.

total demand distortion (TDD): The ratio of the root-mean-square of the harmonic content, considering harmonic components up to the 50th order and specifically excluding interharmonics, expressed as a percent of the maximum demand load current. Harmonic components of order greater than 50 may be included when necessary.

total harmonic distortion (THD): The ratio of the root- mean- square of the harmonic content, considering harmonic components up to the 50th order and specifically excluding interharmonics, expressed as a percent of the fundamental. Harmonic components of order greater than 50 may be included when necessary.

*Additional text was added to give guidance on calculating the **maximum demand load current on** proposed new systems and when historical load data is limited. The maximum demand load current now includes the fundamental and harmonic currents. This is the total current and not just the fundamental current. The definition for the maximum demand load current states "apparent power demand": this is the kVA which includes kW, kVAR and distortion kVA.*

8. Added in **4.0 Harmonic measurements**:

"For purposes of IEEE 519 evaluation, measurements shall be made at least up to the 50th order."

Past revisions looked at up to the 50th order. There may be some cases where higher orders should be considered. For example, when drives with active rectifiers are used.

Changed Table 1 in **5.1 Voltage distortion limits by** adding "h ≤ 50" in the heading for **Individual harmonic (%):**

Bus voltage V at PCC	Individual harmonic (%) h ≤ 50	Total harmonic distortion THD (%)
$V \leq 1.0$ kV	5.0	8.0
1 kV < $V \leq 69$ kV	3.0	5.0
69 kV < $V \leq 161$ kV	1.5	2.5
161 kV < V	1.0	1.5[a]

Individual harmonics have typically been considered to the 50th harmonic in the past. Some have questioned the impact of higher order harmonics with drives with active rectifiers, but typical data for our Active Front End drives shows very small magnitudes for harmonics over the 50th, so they generally have almost no effect on the overall THD %.

9. Added statement in 5.3 Current distortion limits for systems nominally rated 120 V through 69 kV:

   "These limits shall not be used for the evaluation of an individual nonlinear load, but rather, for the evaluation of the installation containing such nonlinear loads."

   This statement reinforces the intent that has always been present in previous revisions; That the standard is for the evaluation of systems with nonlinear loads, but not for an individual nonlinear load, like at the input of an individual drive, for example.

10. Changed Table 2 and footnotes in **5.3 Current distortion limits for systems nominally rated 120 V through 69 kV**:

Maximum harmonic current distortion in percent of I_L						
Individual harmonic order[b]						
I_{SC}/I_L	$2 \le h < 11$[a]	$11 \le h < 17$	$17 \le h < 23$	$23 \le h < 35$	$35 \le h \le 50$	TDD
< 20[c]	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

a For $h \le 6$, even harmonics are limited to 50 ~~25~~% of the ~~odd~~ harmonic limits shown in the table ~~above~~.

b Current distortions that result in a dc offset, e.g., half-wave converters, are not allowed.

c ~~All~~ Power generation ~~equipment is~~ facilities are limited to these values of current distortion, regardless of actual I_{SC}/I_L unless covered by other standards with applicable scope.

where:

I_{SC} = maximum short-circuit current at PCC

I_L = maximum demand load current ~~(fundamental frequency component)~~ at ~~the~~ PCC under normal load operating conditions

As noted in the second title and footnote a: The even harmonic limits are now the same as the odd harmonic limits except for 2nd, 4th and 6th which are limited to 50% of the limits shown.
As noted in footnote c: There was a perception that when drives are running on back-up gensets within a facility, the TDD needed to meet 5.0%. This footnote clearly states that is not the case. Even though it is not stated, the case could be made that the voltage distortion is the key parameter to limit when operating on a back-up genset while the facility is not connected to the utility power grid.
As noted in the "where:" section: The calculation of TDD was changed from (Iharm / Ifund) to (Iharm / Itotal), where Itotal = the RSS (square root of the sum of the squares) of Ifund and Iharm. This means that the denominator for that calculation increased a small amount, making the TDD value a bit smaller than before.

For example: If Ifund = 100A, Iharm = 40A, then Itotal = 107.70A
TDD was = 40/100 = 40%, but now TDD = 40/107.7 = 37.14%

11. The tables and footnotes in the other current distortion limits tables are similar. They cover voltages greater than 69kV and thus will not be discussed here since they would rarely apply to our applications.

12. Changed Table 5 of **5.6 Recommendations for increasing harmonic current limits**:

Harmonics orders limited to 25% of values given in Table 2, Table 3, and Table 4	Multiplier
5, 7	1.4
5,7,11,13	1.7
5,7,11,13,17,19	2.0
5,7,11,13,17,19,23,25	2.2
↓	Multiplier = $\sqrt{\frac{p}{6}}$

A minor change where the equation for the multiplier is included within the table instead of being separate. It does state that the method used to reduce these harmonics is not limited to increasing the pulse number by using phase-shifting transformers along with additional diode bridges, but may include filters, AFE rectifiers, etc. If the method used does reduce the noted harmonic orders to less than 25% of the limit, the multiplier can be applied to the other individual harmonic limits.

13. Change in **Annex A on Interharmonic voltage limits (informative)**:

This discusses previous limits and proposed limits.

Regarding the proposed limits, they state, "These limits appear to be very restrictive so they should be applied if sensitive equipment are installed, and a risk analysis has shown their necessity." Also, they state, "Moreover, IEEE Std 519-2014 [B6] and IEC 61000-2-2 [B4] rely on the IEC Flickermeter to assess voltage limits around the fundamental due to the difficulties in measuring very low voltage magnitudes with available instruments compliant with IEC 61000-4-7 [B5]."

14. No significant changes in **Annex B on Telephone influence factor (TIF) (informative)**.

15. No significant changes in **Annex C on Limits on commutation notches (informative)**.

16. Additional papers and standards were added to **Annex D on Bibliography (informative)**, and some were removed.

Summary:

Previous versions of IEEE-519 were considered recommended practices and requirements, but now this is considered a standard. Overall, the changes are relatively minor.

The calculation for TDD% changes by using Itotal instead of Iharm in the calculation making values a bit smaller.

The limits for even harmonics have changed.

IEEE 519-2022 may not apply in some applications where a significant amount of power (10%) is being injected into the utility power grid by way of regenerative rectifiers or generators. More information on back-up generators that are not connected to the grid versus power generation equipment that is grid connected is available in an ABB Technical Note titled "*Back-up generators and harmonic levels*" Document number LVD-EOTKN127U

This document references the following IEEE standards and ABB Tech Notes:

- IEEE Std 519™-1992, IEEE Std 519™-2014, IEEE Std 519™-2022
- IEEE Std 1547-2018
- IEEE Std 2800-2022
- LVD-EOTKN127U Back-up generators and harmonic levels