QUALITY ENERGY

UNDERSTANDING THE IEEE 519 – 2014 STANDARD FOR HARMONICS

The IEEE 519-2014 standard defines the voltage and current harmonics distortion criteria for the design of electrical systems. The existed voltage and current waveforms in every part of the system are explained in this standard, and the waveform distortion goals for the system designer are established.
The standard is periodically updated as the industry evolves. Since its introduction in 1981, the standard has been updated several times and its latest edition is IEEE 519-2014. Some updates have been made by 2022 . The main terms definitions and statistical evaluation technics are being covered within this current article, as the main changes that have been made in the standard were described in the IEEE-519 2014 edition.

DEFINITIONS OF IMPORTANT TERMS IN THE IEEE 519

1. **New Definitions**
    - **Maximum demand load current:** This current value is enacted at the point of common coupling (PCC) and calculates as the average of the currents corresponding to the peak demand during the previous 12 months.
    - **Notch:** A condition, lasting less than ½ cycle, in which the magnitude of the voltage waveform reversed its normal polarity.

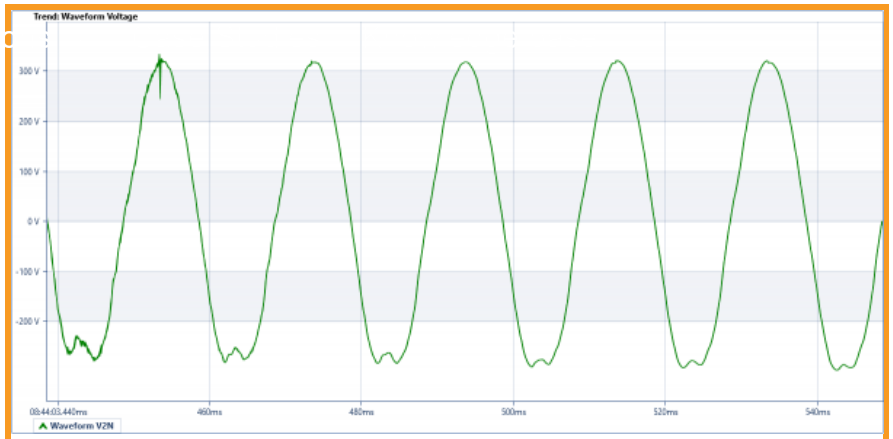
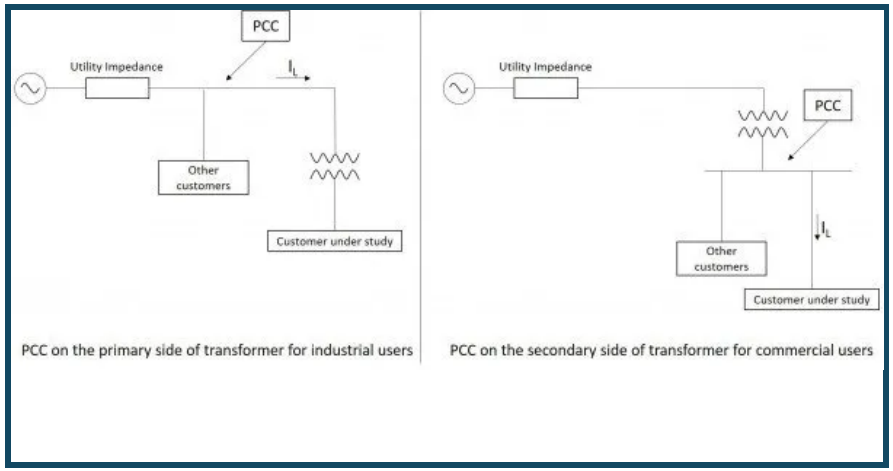


Illustration 1: Notches

    - **Point of common coupling (PCC):** the point on a public power supply system, electrically closest to a specific load, in which other loads are, or maybe connected. The PCC is a point located upstream of the regarded installation.



Total demand distortion (TDD): The ratio of the root mean square of the harmonic content, including the harmonic components up-to the 50th order. Expressed as a percent of the maximum demand current. Inter-harmonics are specifically excluded. Higher frequencies (harmonics greater than 50) may be added when required.

- **Total harmonic distortion (THD):** The ratio of the root mean square of the harmonic content, including the harmonic components, up-to the 50th order. Expressed as a percent of the fundamental. Inter-harmonics are specifically excluded. Higher frequencies (harmonics greater than 50) may be added when required.

3. **Legacy definitions**

- **Harmonic (component):** An element of order more than one of the Fourier series of a periodic quantity. For instance, in a 60 Hz system, the harmonic order 3, commonly known as the “third harmonic,” is 180 Hz.
- **Inter-harmonic (component):** Refers to the frequency component of a periodic quantity that isn’t an integer multiple of the frequency in which the supply system operates (for instance, 50 Hz or 60 Hz).
- **I-T product:** The inductive influence is expressed as regards the product of the root-mean-square current magnitude (I), in amperes, times its telephone influence factor (TIF).
- **kV-T product:** Inductive influence expressed as regards the product of root-mean-square voltage magnitude (V), in kilovolts, and times its telephone influence factor (TIF).
- **Notch depth:** The average depth of the line voltage notch from the sine wave of voltage.
- **Notch area:** It is the area of the line voltage notch. It is the product of the notch depth, in volts, times the width of the notch measured in microseconds.

- **Telephone influence factor (TIF):** For a voltage or recent wave in an electric supply circuit, the ratio of adding the square root of the squares of the weighted root-mean-square values of every one of the sine-wave components (with alternating current waves both fundamental and harmonic) to the root-mean-square value (unweighted) of the whole wave.

DIFFERENCES WITH THE PREVIOUS EDITION

IEEE STD 519-1992	IEEE STD 519-2014
Comprehensive discussion about harmonics	Absence of discussion about harmonic fundamentals
Naturally educational and informative	Clarification and limits are setting in nature
Added Total Harmonic Distortion (THD) and Total Demand Distortion (TDD)	Included statistical evaluation technique for Shot time-harmonic measurements (10Min resolution) and very short time harmonic measurement (3Sec resolution)

IEEE STD 519-1992	IEEE STD 519-2014
It focuses on: • Suggested practices for single consumers • Suggested practices for Utilities • Suggested methodology for examining the latest harmonic	It focuses on: • Voltage and current harmonic measurements • Suggested limitation for voltage and current harmonic distortion.

NEW MEASUREMENT METHOD AND STATISTICAL EVALUATION TECHNIQUE

The IEEE 519-2014 introduce a newly measurement methods and statistical evaluation technique to determine compliance with the recommended limits.

HARMONICS MEASUREMENT METHODS

The standard adopt the 10/12 cycles gapless harmonic subgroup measurement from the IEC 61000-4-7. Aggregations of 150/180 cycles (~3sec) and 10min are required for the statistical assessments.

Very short time harmonic measurements

$$F_{n,vs} = \sqrt[2]{\frac{1}{15}\sum_{i=1}^{15} F_{n,i}^2}$$

- Short time harmonics measurements
  Short time harmonic values are assessed over a 10-minute interval based on an aggregation of 200 consecutive very short time values for a specific frequency component. The 200 values are aggregated based on an RMS calculation as shown in Equation (2) where F represents voltage (V) or current (I), n represents the harmonic order, and i is a simple counter. The subscript sh is used to denote “short.” In all cases, F represents an RMS value.

$$F_{n,vs} = \sqrt[2]{\frac{1}{200}\sum_{i=1}^{200} F_{(n,vs),i}^2}$$

STATISTICAL EVALUATION

Daily evaluation

It is required to calculate the 99th percentile value (i.e. the value that is exceeded for 1% of the day) of the very short time harmonics values for comparison with the recommend limits.

THE IEEE 519 – 2014 COMPLIANCE CRITERIA

transformer's HV side. For most commercial users like office parks, etc., supplied through a usual service transformer, the PCC is commonly at the LV side of the service transformer.

VOLTAGE DISTORTION LIMITS

- Daily 99th percentile very short time (3 s) values should be less than 1.5 times the values given in the table below.
- Weekly 95th percentile short time (10 min) values should be less than the values given in the table below.

TABLE 1 (IEEE 519-2014)

	Weekly 95th percentile short time		Daily 99th percentile short time	
Bus voltage V at PCC	Individual harmonic (%)	THD (%)	Individual harmonic (%)	THD (%)
$V \leq 1.0$ kV	5.0	8.0	7.5	12
1 kV < $V \leq 69$ kV	3.0	5.0	4.5	7.5
69 kV < $V \leq 161$ kV	1.5	2.5	2.25	3.75

Weekly 99th percentile short time (10 min) harmonic currents should be less than 1.5 times the values given in tables below.

- Weekly 95th percentile short time (10 min) harmonic currents should be less than the values given in tables below.

Table 2 (IEEE 519-2014) Current distortion limits for systems rated 120 V – 69 kV

I_{SC}/I_L	Individual harmonic limits (Odd harmonics) [a,b] Harmonics values are in % of maximum demand load current					TDD
	3 ≤ h < 11	11 ≤ h < 17	17 ≤ h < 23	23 ≤ h < 35	35 ≤ h ≤ 50	
<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

Table 3 (IEEE 519-2014) Current distortion limits for systems rated 69 kV – 161 kV

I_{SC}/I_L						TDD
	3 ≤ h < 11	11 ≤ h < 17	17 ≤ h < 23	23 ≤ h < 35	35 ≤ h ≤ 50	
<20	2.0	1.0	0.75	0.3	0.15	2.5
20<50	3.5	1.75	1.25	0.5	0.25	4.0
50<100	5.0	2.25	2.0	0.75	0.35	6.0
100<1000	6.0	2.75	2.5	1.0	0.5	7.5
>1000	7.5	3.5	3.0	1.25	0.7	10.0

Table 4 (IEEE 519-2014) Current distortion limits for systems rated > 161 kV[a]

I_{SC}/I_L	Individual harmonic limits (Odd harmonics) [a,b] Harmonics values are in % of maximum demand load current					TDD
	3 ≤ h < 11	11 ≤ h < 17	17 ≤ h < 23	23 ≤ h < 35	35 ≤ h ≤ 50	
<25	1.0	0.5	0.38	0.15	0.1	1.5
20<50	2.0	1.0	0.75	0.3	0.15	2.5
≥50	3.0	1.5	1.15	0.45	0.22	3.75

[a] Even harmonics are limited to 25% of the odd harmonic limits above

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

[c] All power generation equipment is limited to these vales of current distortion, regardless of actual I_{SC}/I_L.

I_{SC} = maximum short circuit current at PCC

I_L = maximum demand load current (fundamental frequency component) at PCC

HOW THE IEEE 519-2014 CHALLENGES TRADITIONAL POWER QUALITY ANALYZERS

The need to assessing harmonics values at resolution of 3sec challenging traditional power quality analyzers memory limitation. Within 1 week, it is required to record 201,600 3sec intervals per individual harmonic per phase which result 60,480,000 parameters in total (excluding THD and TDD). With 4Bytes per parameter the required memory for only 1 week worth of data is 240MB. Most power quality analyzers don't have sufficient memory to hold this data. Therefore, the statistical evaluation calculation perform within the meter in real time and only summary data which contain a daily/weekly pass/fail results is recorded. This technic that overcome memory limitations have some drawbacks:

- The harmonic current distortion value are in percent of I_L (Maximum demand load current). Therefore, in case that the I_L value is not available (New installation or portable applications) or misconfigured the compliance assessment cannot be achieved.
- The harmonics current distortion criteria limits are function of the I_{SC} to I_L Therefore, if one of this parameter is not available during installation or misconfigured the compliance assessment will be wrong.