IEEE Standard 519-2014

Compliances, Updates, Solutions and Case Studies

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Agenda

1. Introduction: Harmonics Overview
2. History of IEEE STD 519, and comparison between IEEE STD 519 (2014 vs 1992)
3. How SE helped you to achieve IEEE STD 519-2014
4. Case Studies
5. Conclusions

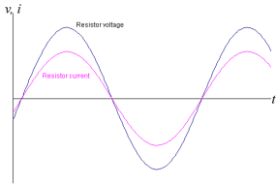
Introduction

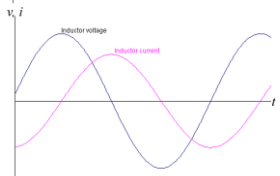
Harmonics Overview

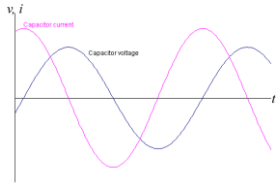
Why is there harmonic in the electrical network?

Linear loads versus Nonlinear loads

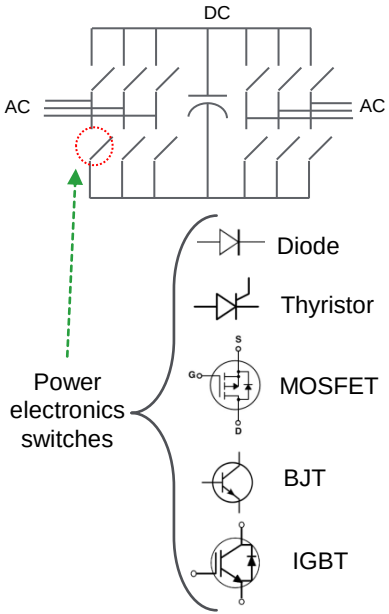
Linear loads:







Nonlinear loads:

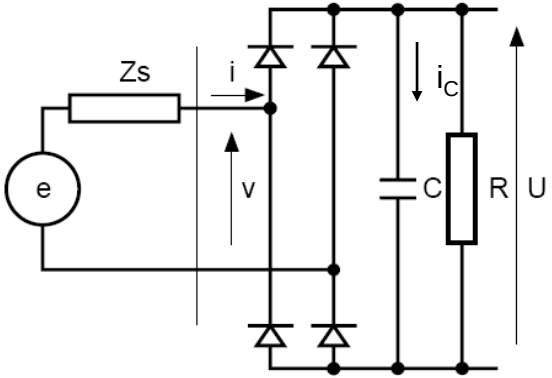


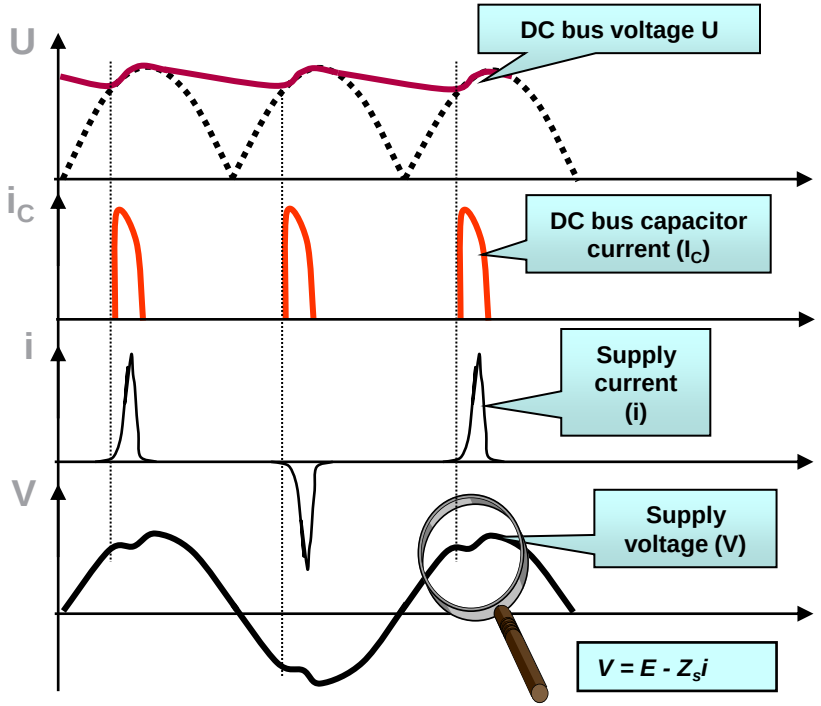
Type of Load	Typical Waveform	Current Distortion
Single Phase Power Supply		80% (high 3rd)
Semiconverter		high 2nd,3rd, 4th at partial loads
6 Pulse Converter, capacitive smoothing, no series inductance		80%
6 Pulse Converter, capacitive smoothing with series inductance > 3%, or dc drive		40%
6 Pulse Converter with large inductor for current smoothing		28%
12 Pulse Converter		15%
ac Voltage Regulator		varies with firing angle
Fluorescent Lighting		20%

Source: IEC 61000-3-6:1996

How does the harmonic created?

Single phase full-bridge rectifier circuit

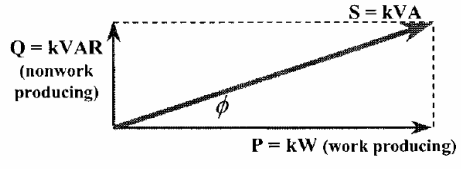


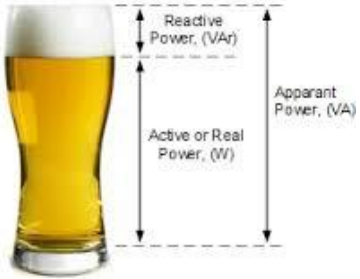


“Evolution” of Power Factors

With linear vs. nonlinear loads

Electrical system with ONLY linear loads

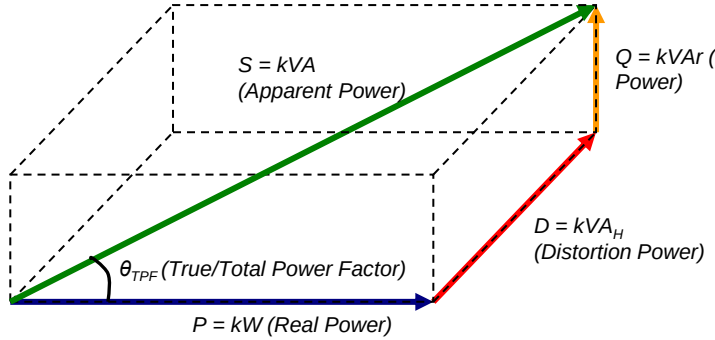




$$S(kVA) = \sqrt{P^2 + Q^2} = \sqrt{kW^2 + kVAr^2}$$

$$\text{power factor, } \cos\phi = \frac{P}{S} = \frac{kW}{kVA}$$

Electrical system with Nonlinear loads



$$S(kVA) = V_{rms}\, I_{rms} = \sqrt{P^2 + Q^2 + D^2}$$

True/Total Power Factor : $\cos\theta_{TPF} = \cos\theta_{dispPF} \cdot \cos\theta_{distPF}$

Displacement Power Factor (Fundamental Components): $\cos\theta_{dispPF} = \frac{kW}{kVA(\,fundamental)}$

Distortion Power Factor (Harmonic Components): $\cos\theta_{distPF} = \frac{1}{\sqrt{1+THD_v^2}\sqrt{1+THD_i^2}}$

Effects of Harmonics

Different Perspectives

Engineering Perspective

- Nuisance tripping of circuit breaker
- Harmonic resonance
- Capacitor bank failure
- Excessive heating
- Transformer overheating
- Skin effects on cables for higher harmonic orders
- Motor winding burnt (dv/dt) & hunting
- Neutral overloading (double neutral)
- Causing EMI to sensitive signals
- Problems to generators

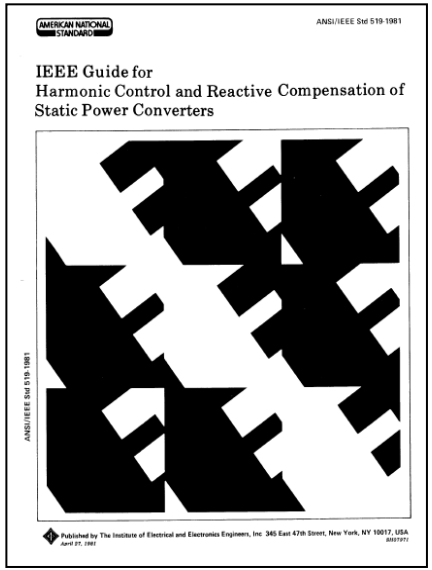
Business Perspective

- Increased maintenance and replacement cost (OPEX)
- Interruptions and downtimes cost
- Reduced system capacity and thus increase CAPEX by unnecessary of expansion.

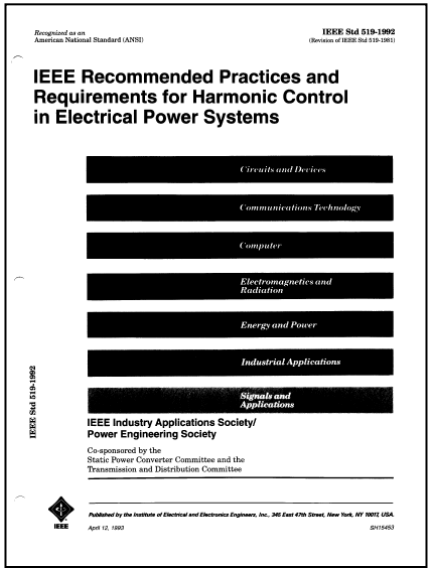
History of IEEE Standard 519

The Journey of IEEE Standard 519

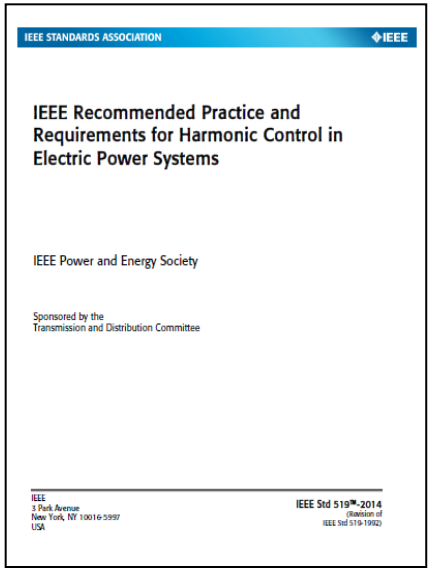
Revision Years: 1981, 1992 and 2014



Sponsor by Static Power Converter Committee of the Industry Applications Society



Sponsors by Transmission & Distribution Committee of the IEEE Power Engineering Society and Static Power Converter Committee of the IEEE Industry Applications Society



Sponsor by Transmission & Distribution Committee of the IEEE Power Engineering Society

Main Focuses

Shifting of main focuses depending on the sponsors.

IEEE STD 519-1981

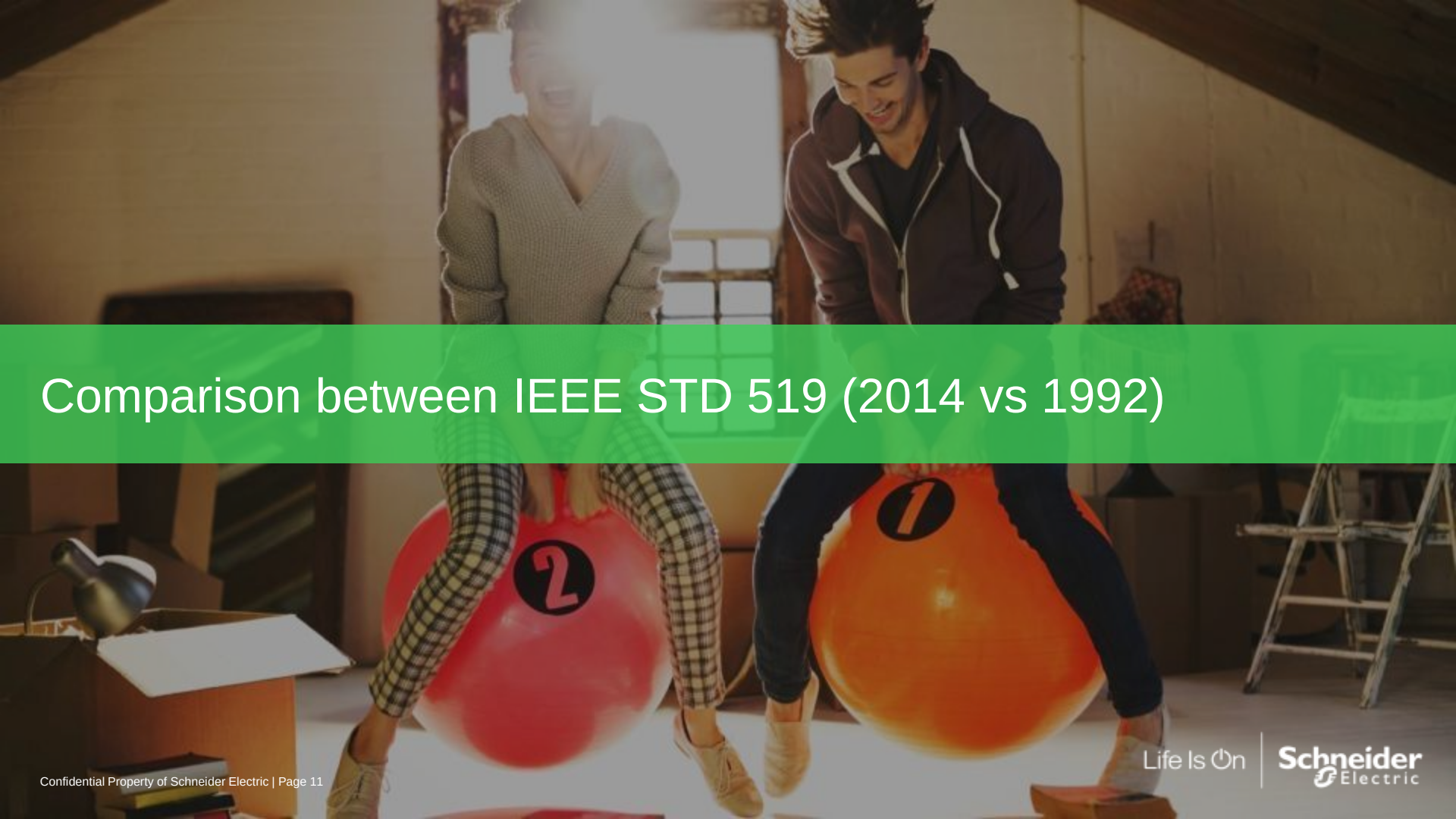
- Title: IEEE Guide for Harmonic Control and Reactive Compensation of Static Power Converters (54 pages)
- Sponsor : Static Power Converter Committee (SPCC) of the Industry Applications Society (IAS)
- Introduce the basic of harmonics.
- Educational in nature
- Introduces quantifying factor for harmonics such as DF, TIF
- Focus on the recommended practices for:
  - Line notch limits
  - Voltage distortion limits
  - Telephone influence limits
  - Flicker limits

IEEE STD 519-1992

- Title: IEEE Recommended Practices and Requirements for Harmonic Control in Electrical Power System s(101 pages)
- Sponsors: Transmission & Distribution Committee of the IEEE PES & SPCC of the IEEE IAS
- In-depth discussion about harmonics
- Educational and informative in nature.
- Introduces Total Harmonic Distortion (THD) and Total Demand Distortion (TDD).
- Focus on:
  - Recommended practices for Individual consumers
  - Recommended practices for Utilities
  - Recommended methodology for evaluating new harmonic sources

IEEE STD 519-2014

- Title: IEEE Recommended Practice and Requirements for Harmonic Control in Electrical Power System s(29 pages)
- Sponsor: Transmission & Distribution Committee of the IEEE Power Engineering Society (PES)
- No discussion about harmonic fundamentals
- Clarification and limits setting in nature.
- Introduces statistical evaluation (Very short and Shot time harmonic measurements)
- Focus on:
  - Harmonic measurements
  - Recommended harmonic limits for voltage and current distortion



Comparison between IEEE STD 519 (2014 vs 1992)

Section 1: Overview

Section 1.1: Scope

Section 1.2: Purpose

IEEE Standard 519 - 2014

Redefining the Purpose of IEEE 519 in 2014 document

Focusing on Point of Common Coupling (PCC)

IEEE STD 519-1992

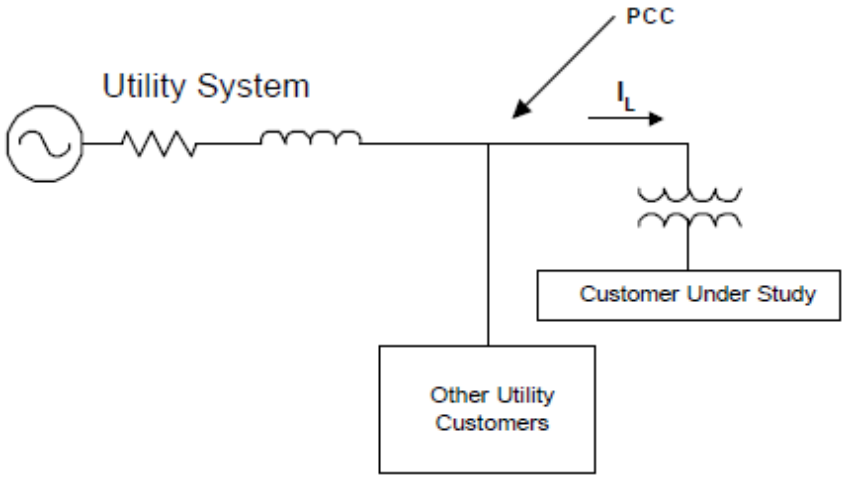
- Page 75. Focuses on the PCC with the consumer-utility interface, but contradicting definition of PCC in latter statement.
- The recommendation described in this document attempts to reduce the harmonic effects at any point in the entire system by establishing limits on certain harmonic indices (currents 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.

IEEE STD 519-2014

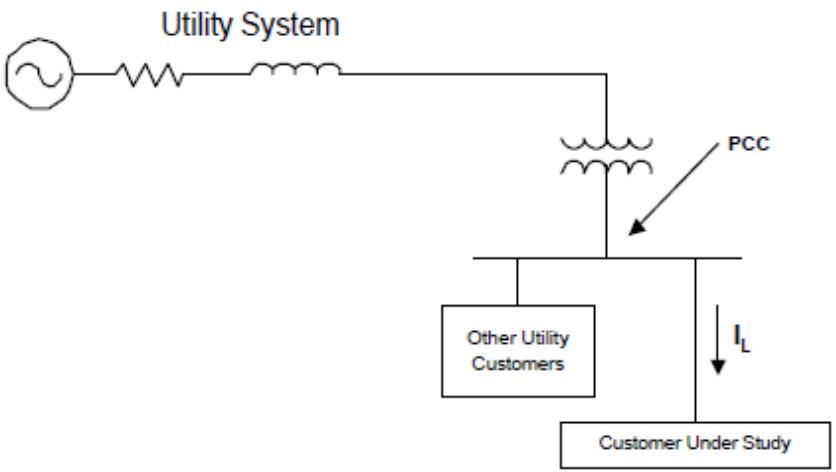
- Page 2. Clarify on the PCC.
- The limits in this recommended practice are intended for application at a point of common coupling (PCC) between the system owner or operator and a user, where the PCC is usually taken as the point in the power system closest to the user where the system owner or operator 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.

Point of Common Coupling in Summary

IEEE STD 519-2014



PCC at HV side for Industrial users



PCC at LV side for commercial users

Who’s Responsibility?

Utility and/or Users?

IEEE STD 519-1992

- Mentioned briefly in the “Foreword” page. Not considered as part of the standards guidelines.
- 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.

IEEE STD 519-2014

- Listed clearly in “Section 1.2 - Purpose” (page 2)
- The limits in this recommended practice represent a shared responsibility for harmonic control between system owners or operators and users.
- Maintaining harmonic voltages below these levels necessitates that
  - All users limit their harmonic current emissions to reasonable values determined in an equitable manner based on the inherent ownership stake each user has in the supply system and
  - Each system owner or operator takes action to decrease voltage distortion levels by modifying the supply system impedance characteristics as necessary.

Section 2: Normative References

IEEE Standard 519 - 2014

References

IEEE STD 519-2014 reference to IEC61000-4-X

IEEE STD 519-1992

- Page 8
- 10 references.
- All references are referenced to IEEE Standards and ANSI (American National Standard)

IEEE STD 519-2014

- Page 3
- 4 references, but 2 are the same (IEC 61000-4-15 and IEEE STD 1453)
- All references are referenced to IEC Standards.
  - IEC Standard 61000-4-7, General Guide on Harmonics and Interharmonics Measurement and Instrumentation, for Power Supply Systems and Equipment Connected Thereto.
  - IEC Standard 61000-4-30, Power Quality Measurement Methods.
  - IEC Standard 61000-4-15, Testing and Measurement Techniques—Flickermeter—Functional and Design Specifications.
  - IEEE Std 1453™, IEEE Recommended Practice—Adoption of IEC 61000-4-15:2010, Electromagnetic compatibility (EMC)—Testing and Measurement Techniques—Flickermeter—Functional and Design Specifications

Section 3: Definitions

IEEE Standard 519 - 2014

New and Redefined Definitions

IEEE STD 519-2014 – page 3

New Definitions

- **maximum demand load current**: This current value is established at the point of common coupling and should be taken as the sum of the currents corresponding to the maximum demand during each of the twelve previous months divided by 12.
- **notch**: A switching (or other) disturbance in the normal power voltage waveform, lasting less than 0.5 cycles, which is initially of opposite polarity than the waveform and is thus subtracted from the normal waveform in terms of the peak value of the disturbance voltage. This includes complete loss of voltage for up to 0.5 cycles.
- **point of common coupling** (PCC): Point on a public power supply system, electrically nearest to a particular load, at which other loads are, or could be, connected. The PCC is a point located upstream of the considered installation.

Redefined Definitions

- short-circuit ratio: At a particular location, the ratio of the available short-circuit current, in amperes, to the load current, in amperes.
- 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 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.

Section 4: Harmonic Measurements

Section 4.1: Measurement window width
Section 4.2: Very short time harmonic measurements
Section 4.3: Short time harmonic measurements
Section 4.4: Statistical evaluation

IEEE Standard 519 - 2014

Instrument Compliances

New compliance guidelines (IEC 61000-4-7 & IEC 61000-4-30)

IEEE STD 519-1992

- Page 68-74, Section 9: Measurement
- Detailing all the requirements for harmonic measurement
  - 9.2 Basic Equipment Used for the Analysis of Nonsinusoidal Voltages and Currents
  - 9.3 Requirements for Instrument Response
  - 9.4 Presentation of Harmonic Data
  - 9.5 Transducers for Harmonic Measurements

IEEE STD 519-2014

- Page 4
- Reference directly to IEC Standards. No reproduction of IEEE STD 519-1992 Section 9.
- For the purposes of assessing harmonic levels for comparison with the recommended limits in this document, any instrument used should comply with the specifications of IEC 61000-4-7 and IEC 61000-4-30.

New Terminologies for Harmonic Measurements

Newly introduced in IEEE STD 519-2014 page 5, and not in IEEE STD 519-1992.

Very short time harmonic measurements

- Very short time harmonic values are assessed over a 3-second interval based on an aggregation of 15 consecutive 12 (10) cycle windows for 60 (50) Hz power systems.
- Individual frequency components are aggregated based on an rms calculation as shown in Equation (1).

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

- where
  - F represents voltage (V) or current (I) in rms value.
  - n represents the harmonic order,
  - i is a simple counter
  - Subscript vs = “very short.”

Short time harmonic 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).

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

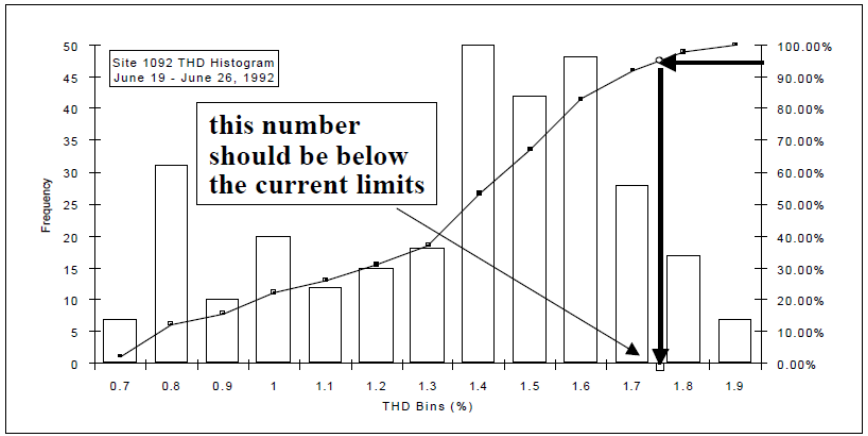
- where
  - F represents voltage (V) or current (I), in rms value
  - n represents the harmonic order
  - i is a simple counter
  - Subscript sh is =“short.”

Specify Durations and Statistical Evaluation

IEEE STD 519-2014 Pg 5; & IEEE STD 519-1992 no duration and only has 95th percentile.

Very short time harmonic measurements

- Measurement duration: 24 hours (1 day)
- For very short time harmonic measurements, the 99th percentile value (i.e., the value that is exceeded for 1% of the measurement period) should be calculated for each 24-hour period for comparison with the recommend limits in Clause 5.
- Applied to both voltage and current harmonics.



Short time harmonic measurements

- Measurement duration: 7-day period (1 week)
- For short time harmonic measurements, the 95th and 99th percentile values (i.e., those values that are exceeded for 5% and 1% of the measurement period) should be calculated for each 7-day period for comparison with the recommended limits in Clause 5.
- These statistics should be used for both voltage and current harmonics with the exception that the 99th percentile short time value is not recommended for use with voltage harmonics.
- Interpretation:
  - Current harmonics evaluate based on 95th and 99th percentile.
  - Voltage harmonics evaluate based on 95th percentile only.

Section 5: Recommended harmonic limits

Section 5.1: Recommended harmonic voltage limits
Section 5.2: Recommended current distortion limits for systems nominally rated 120 V through 69 kV
Section 5.3: Recommended current distortion limits for systems nominally rated above 69 kV through 161 kV
Section 5.4: Recommended current distortion limits for systems nominally rated above 161 kV
Section 5.5: Recommendations for increasing harmonic current limits

IEEE Standard 519 - 2014

General Observations

Individual responsibilities

IEEE STD 519-1992

- Separate the recommended practices between individual consumers and utilities
- Individual consumers:
  - Recommended harmonic indices for are:
    - (1) Depth of notches, total notch area, and distortion of bus voltage distorted by commutation notches (low-voltage systems)
    - (2) Individual and total voltage distortion
    - (3) Individual and total current distortion
  - PCC can be between the nonlinear load and other loads.
- Utilities:
  - Recommended harmonic indices is only maximum voltage distortion at the point of common coupling (PCC) with each consumer.

IEEE STD 519-2014

- Reiterate the joint responsibility involving both end-users and system owners or operators, that harmonic limits are recommended for both voltages and currents.
- Both system owners or operators and users must work cooperatively to keep actual voltage distortion below objectionable levels
  - End-users limit the harmonic current injections
  - System owners or operators should take action to modify system characteristics so that voltage distortion levels are acceptable in case the efforts by end-users are insufficient.
- The recommended limits in this clause apply only at the PCC and should not be applied to either individual pieces of equipment or at locations within a user's facility.

Harmonic Voltage Limits

New limits for Low Voltage (<1kV) & Percentiles in IEEE STD 519-2014

IEEE STD 519-1992

- Consumers' harmonic voltage limits based on line-to-line voltage:

Table 10.2
Low-Voltage System Classification and Distortion Limits

	Special Applications*	General System	Dedicated System†
Notch Depth	10%	20%	50%
THD (Voltage)	3%	5%	10%
Notch Area (A_N)‡	16 400	22 800	36 500

NOTE: The value A_N for other than 480 V systems should be multiplied by V/480

*Special applications include hospitals and airports.
†A dedicated system is exclusively dedicated to the converter load.
‡In volt-microseconds at rated voltage and current.

- Utilities:

Table 11.1
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.

IEEE STD 519-2014

- At the PCC, system owners or operators should limit line-to-neutral voltage harmonics as follows:
  - Daily 99th percentile very short time (3 s) values should be less than 1.5 times the values given in Table 1.
  - Weekly 95th percentile short time (10 min) values should be less than the values given in Table 1.
- Notches limits moved to Annex C (Informative).

Table 1—Voltage distortion limits

Bus voltage V at PCC	Individual harmonic (%)	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]

[a]High-voltage systems can have up to 2.0% THD where the cause is an HVDC terminal whose effects will have attenuated at points in the network where future users may be connected.

Current Distortion Limits

General observations

IEEE STD 519-1992

- The harmonic distortion caused by a single consumer should be limited to an acceptable level at any point in the system.
- TDD: Total demand distortion, harmonic current distortion in % of maximum demand load current (15 or 30 min demand). No limits on harmonic orders.
- The limits listed in Tables 10.3, 10.4, and 10.5 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%. (up to 1 hour per day, which is equivalent to about 4.1% of the time. Thus, 95th percentile is used.)
- Both the recommended current distortion limits for 120V to <69kV and 69kV to <161kV in both standards are the same, except the TDD calculation is up to 50th harmonic order.

IEEE STD 519-2014

- Newly defined limits based on 3 percentile limits:
  - Daily 99th percentile very short time (3 s) harmonic currents should be less than 2.0 times the values given in the Tables.
  - Weekly 99th percentile short time (10 min) harmonic currents should be less than 1.5 times the values given in Tables.
  - Weekly 95th percentile short time (10 min) harmonic currents should be less than the values given in Tables.
- TDD up to 50th order only.
- The maximum demand current value is established at the PCC and should be taken as the sum of the currents corresponding to the maximum demand during each of the twelve previous months divided by 12.

Current Distortion Limits (120V to <69kV)

Both the same except TDD calculation up to 50th harmonics order.

IEEE STD 519-1992

Table 10.3
Current Distortion Limits for General Distribution Systems
(120 V Through 69 000 V)

Maximum Harmonic Current Distortion in Percent of 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 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.

IEEE STD 519-2014

Table 2—Current distortion limits for systems rated 120 V through 69 kV

Maximum harmonic current distortion in percent of I_L						
Individual harmonic order (odd harmonics)[a, b]						
I_{SC}/I_L	$3 \le h < 11$	$11 \le h < 17$	$17 \le h < 23$	$23 \le h < 35$	$35 \le h \le 50$	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]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 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 the PCC under normal load operating conditions

Current Distortion Limits (>161kV)

Additional new limits in 2014.

IEEE STD 519-1992

Table 10.5
Current Distortion Limits for General Transmission Systems (>161 kV), Dispersed Generation and Cogeneration

	Individual Harmonic Order (Odd Harmonics)					
I_{sc}/I_L	<11	11≤h<17	17≤h<23	23≤h<35	35≤h	THD
<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

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.

IEEE STD 519-2014

Table 4—Current distortion limits for systems rated > 161 kV

Maximum harmonic current distortion in percent of I_L						
	Individual harmonic order (odd harmonics)[a, b]					
I_{sc}/I_L	$3 \le h < 11$	$11 \le h < 17$	$17 \le h < 23$	$23 \le h < 35$	$35 \le h \le 50$	TDD
<25[c]	1.0	0.5	0.38	0.15	0.1	1.5
25 < 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 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 the PCC under normal load operating conditions

Emphasis of Phase-Shifting Transformer & “Multi-pulse” Converter

Both mentioned about the multiplier, but IEEE STD 519-2014 include a Table.

IEEE STD 519-1992

- These tables are applicable to six-pulse rectifiers and general distortion situations.
- However, when phase shift transformers or converters with pulse numbers ***(q) higher than six are used,*** the limits for the characteristic harmonic orders are increased by **a factor equal to**

$$\sqrt{\frac{q}{6}}$$

provided that the amplitudes of the noncharacteristic harmonic orders are less than 25% of the limits specified in the tables.

IEEE STD 519-2014

- However, the recommended multipliers in Table 5 apply regardless of the method used to reduce the harmonics that would be considered “non-characteristic harmonics” for a *p-pulse* converter as long as all “non-characteristic harmonics,” including even-order harmonics, are kept below 25% of the limit values given in Table 2, Table 3, or Table 4 as appropriate.

$$\text{Multiplier} = \sqrt{\frac{p}{6}}$$

Table 5—Recommended multipliers for increases in harmonic current limits

Harmonics orders limited to 25% of values given in Table 2, Table 3, and Table 4	Multiplier	
5, 7	1.4	*p=12*
5,7,11,13	1.7	*p=18*
5,7,11,13,17,19	2.0	*p=24*
5,7,11,13,17,19,23,25	2.2	*p=30*
↓	↓	

Annex: All informative only

- Annex A: Interharmonic voltage limits based on flicker
- Annex B: Telephone influence factor (TIF)
- Annex C: Limits on commutation notches
- Annex D: Bibliography

IEEE Standard 519 - 2014

New Information and Limits on Interharmonic in Annex A

Only an informative page in 2014, but not an enforcement.

IEEE STD 519-1992

- No interharmonic voltage limits
- Included flicker information, limits and solution in pages 80-82, Section 10.5.

IEEE STD 519-2014

- Mentioned in Annex, which is only information.
- Reference to IEC 61000-4-15 (c.f. IEEE STD 1453).

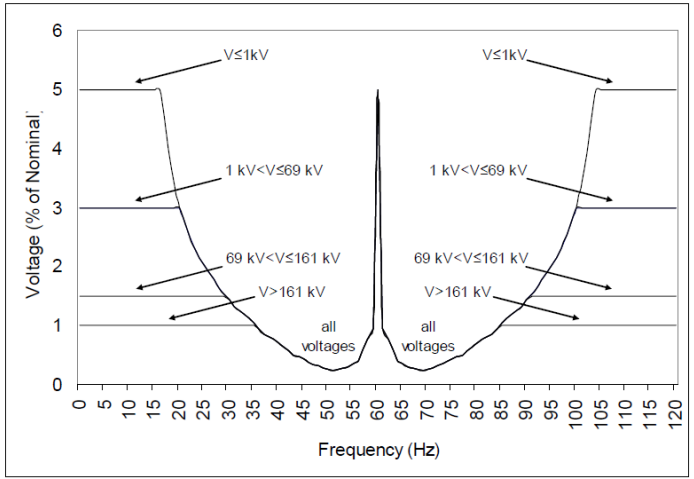


Figure A-1—Interharmonic voltage limits based on flicker for frequencies up to 120 Hz for 60 Hz systems

Simplify Limits on TIF and I-T Product in Annex B

Telephone influence factor (TIF) & I-T product

IEEE STD 519-1992

- TIF:
  - Section 6.9 (pg 40-42), focus on telephone interference.
  - Same content in Table 6.2, but it is renamed to “Table B-1: Weighting values (W_f)” in 2014 document.
- I-T product:
  - Section 11.6 (pg 85-86)
  - Provide different Tables for different types of converters.

IEEE STD 519-2014

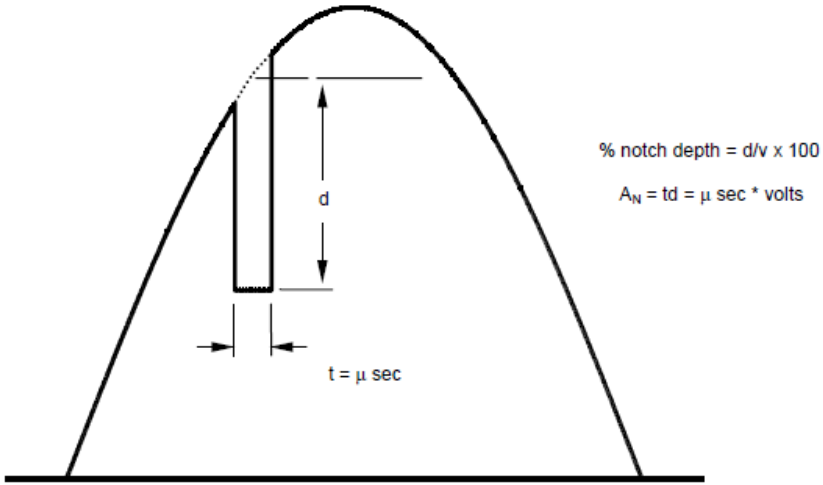
- Mentioned in Annex B, which is only information.
- TIF weighting values Table has the same value as 1992 document, but renamed the title.
- I-T product: Simplified to only 1 table from 1992 document, focusing on distribution systems.

Moved “Limits on Commutation notches” to Annex C

Again “informative” only.

IEEE STD 519-1992

- In Section 10.3 (pg 77), which is part of the ‘Recommended Practices for Individual Consumers’.
- Provide limits in Table 10.2 “Low-Voltage System Classification and Distortion Limits”.



IEEE STD 519-2014

- Moved to Annex C and become informative.
- Rename Table 10.2 to “Table C-1—Recommended limits on commutation notches”. Content is the same.
- Same calculation to determine the notches area.

How SE helped you to achieve IEEE STD 519-2014

SE Complete Solutions for Harmonics and Power Quality

From monitoring to mitigation solutions

Measure:
PME + PQ Advisor + PQ Meters

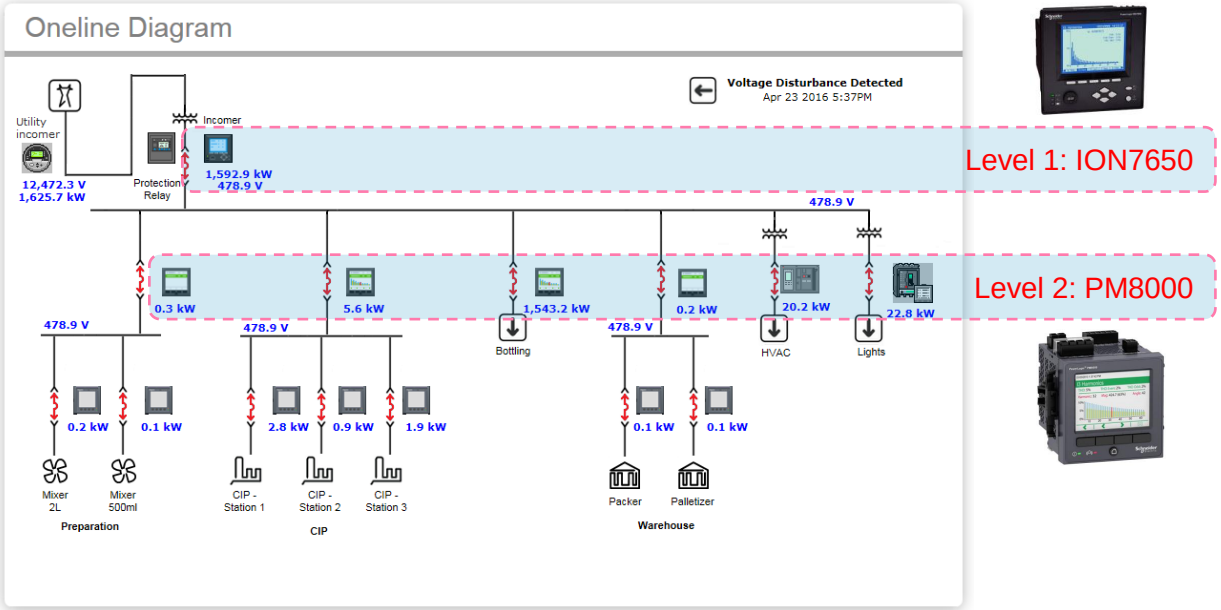
Improve:
Mitigation and correction equipment

Analyze:
PME + PQ Advisor + PQ Experts

- Monitoring Solutions:
  - Hardware: Complied power monitoring devices according to IEC 61000-4-7 & IEC 61000-4-30
    - E.g. ION7550/7650 complied to both IEC 61000-4-7 & IEC 61000-4-30, PM8000 complied to IEC 61000-4-30
    - Capturing individual harmonic orders up to 50th order
  - Software: Power Monitoring System (PME) PQ dashboard to quantify the readings
- Compensation Solutions:
  - Active harmonic filter: AccuSine PCS+ (60A, 120A, 200A, 300A, parallel up to 10 units)
  - Detuned power factor correction capacitor banks
- Services & Expertise: Provide consultation to customers

Where to install PQ Meters?

Level 1 and Level 2 after incoming transformer.

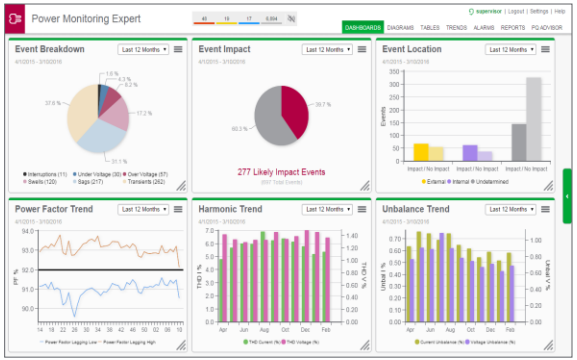


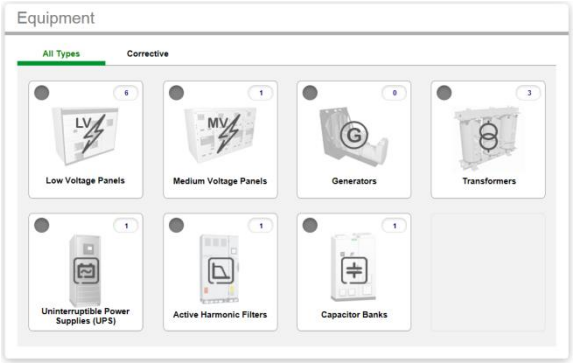
PM8000 key features highlights:

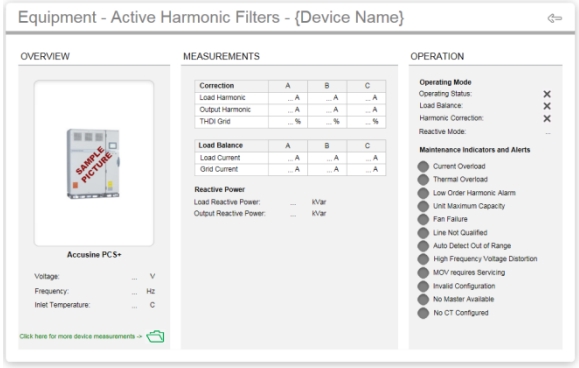
- Architecture:
  - 256 sample/cycle
  - 512MB memory
  - Accuracy Class 0.2S
  - Current & Voltage Accuracy: 0.1% reading
  - Active Energy Accuracy: 0.2%
  - Fast acquisition: 0.5cycle data
- Individual harmonics:
  - 63rd harmonic order on display
  - 127th via PME Software
- Power Quality:
  - Power factor, sag/swell, harmonics, crest factor and K-factor, THD
  - Phasor diagram
  - Waveform capturing.
  - Disturbance direction detection
- Data logging:
  - Revenue, historic, loss, harmonics, energy/demand, sag/swell, EN50160 compliance,IEC61000-4-30 compliance.

PME 8.1 Software

PQ Dashboards, PQ Advisor and Connections to PQ Mitigation Equipments







Demo website: http://pmedemo.biz/

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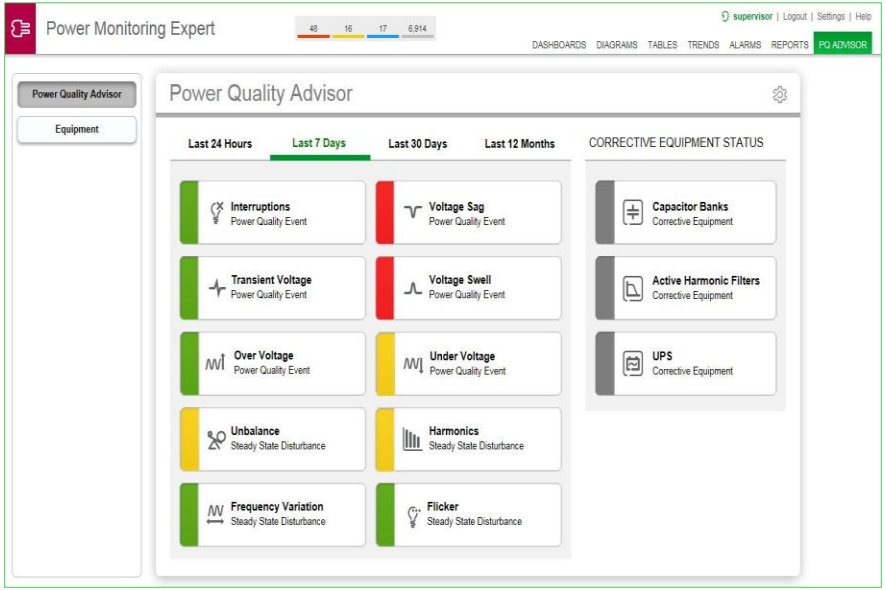
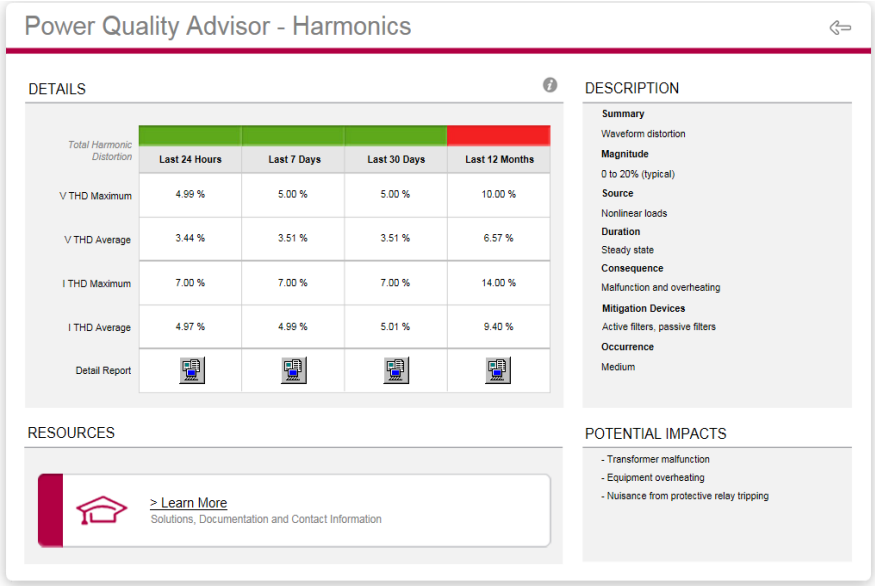
PME 8.1 Software with Power Quality Advisor

PQA Dashboards





Harmonic Compliance Report from PME8.1

How to interpret the report?

Based on IEEE 519-1992 for THDv (<69kV: THDv<5%)

Show number of "3-sec intervals" reading that has exceeded the limits.

Both version have similar TDD table. The TDD limit is based on Isc/IL

Record the highest individual harmonic level during the reporting period.

Show total non-compliance intervals recorded.

Display the "Warning" sign if exceeded the limits.

Voltage Compliance - % of Fundamental		
Voltage Level = 1V	**Individual Voltage Distortion (%)**	**Total Voltage Distortion (THD (%))**
IEEE 519 Limit (%)	3.0	5.0
Maximum Value	-	-
Non-compliant 3-second Intervals	0	0
Missing or Invalid Intervals	0	
Total Intervals	580,800	
% Time out of compliance	0.00	0.00
Compliance	PASS	PASS

Current Compliance - % of IL						
Isc/IL = 40	**Individual Harmonic Order (Odd)**					**TDD (%)**
Ratio Window Limit (20 - 50)	**<11**	**11≤h<17**	**17≤h<23**	**23≤h<35**	**35≤h**	
IEEE 519 Limit (%)	7	3.5	2.5	1	0.5	8
Maximum Value	I2Hrm 3=9.24 @ 5/11/2015 5:06:54 PM	I1Hrm 15=1.85 @ 5/8/2015 3:11:06 PM	I3Hrm 19=4.22 @ 5/10/2015 6:40:45 PM	I3Hrm 23=0.93 @ 5/6/2015 4:12:54 PM	I1Hrm 37=0.31 @ 5/8/2015 3:11:06 PM	I3 TDD=10.4 @ 5/5/2015 4:23:54 PM
Non-compliant Intervals	123,641					60,237
Missing or Invalid Intervals	0					
Total Intervals	580,800					
% Time out of compliance	21.29					10.37
Recommendation	WARNING					WARNING

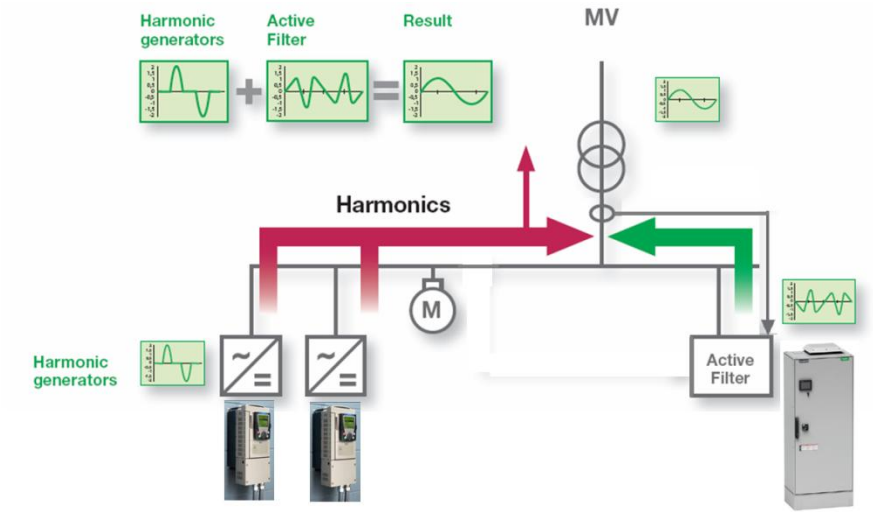
•Total intervals for 24 hours (3 sec intervals) = 28,800
•Total intervals for 7 days (10 min intervals) = 1008

Similar to histogram in terms of percentile:
•95th percentile: limit is <5% out of compliance
•99th percentile: limit is <1% out of compliance

Harmonic ...ce Report - PME8

AccuSine PCS+

Most advanced Active Harmonic Filter



AccuSine PCS+ key features highlights:

- Offer range:
  - 60A, 120A, 200A, 300A @ 380-480 VAC
  - 47A, 94A, 157A, 235A @ 480-600 VAC
  - 40A, 80A, 133A, 200A @ 600-690 VAC
- CE Certified - all models
- Enclosures:
  - IP00 (CH) & IP20 (Type 1) – wall mount
  - IP31, IP54; UL type 2 &12 – Floor Standing
- CT requirements:
  - Primary – ANY amps
  - Secondary – 1 or 5 amps
  - Accuracy Class – Type1
  - Frequency response - 50/60 Hz or 400 Hz
- Logic + Response:
  - Digital – FFT - 2 cycles to inject correction
  - Reactive current response – 1/4 cycle to full response
  - Closed loop – new installations
  - Open loop – for retrofits
  - Control Response – 25 µSec
- Paralleling:
  - Load Share or Lead-Lag
  - Proprietary CAN+ communications bus
  - Master-Slave/MultiMaster-MultiSlave
- Performance:
  - Harmonic spectrum: 2nd to 51st (independently adjustable)
  - Harmonic THD: Closed Loop: <3% THD(i); max 20:1
  - Open Loop: <5% TDD (for retrofit)
  - Set point % THDv
  - Set point %THDi
  - Reactive (leading or lagging to unity PF)
  - Mains current balancing (negative sequence)

AccuSine PCS+ Performance video

Case Studies

International Oil & Gas Customer

Oil & Gas

Toronto, Ontario, CANADA

Electrical Infrastructure upgrade at the Customer ABC Terminal

Customer is looking for energy efficiency and wants to comply with the industry rules and regulations

- **Installation of VFD's to reduce consumption**
- **Correction of the P.F.**
- **Meet IEEE 519-2014**

Energy Efficiency / Space constraints

- The use of VFD's reduces the kW/h consumption, however generates harmonics.
- The constant pumping load (DOL motors) generate a lagging Power Factor.
- Limited space available in the E-House

Issues addressed

- Mitigates the harmonics (V & I) and meets IEEE 519-2014
- Correct the PF to 95% lagging
- Compact PQ solution

AccuSine+

Success Story:

•The use of the AccuSine PCS+ allowed us to use one filter to mitigate the harmonics of 7 VFD's ranging from 40 to 150 HP.

•Simultaneously we correct the PF of the DOL motors to 95% lagging eliminating the PF penalty.

•Supply a compact state of the art Power Solution that meets all the customer needs.

•The AccuSine PCS+ eliminates the need for complex harmonic study.

•The AccuSine PCS+ is compatible with the back up generator.

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International F&B Customer

Food & Beverage

Kejayan, Jawa Timur, INDONESIA

F&B manufacturing facing PQ problem

High harmonic current level, that need to be reduced

- **Harmonic mitigation**
- **Correction of the P.F.**
- **Meet IEEE 519-2014**

•High transformer temperature due to harmonic current

•Nuisance tripping of the breaker

Issues addressed

- Mitigates the harmonics and meets IEEE 519-2014
- Correct the PF

AccuSine+

Success Story:

•Install 3 x 300A Accusine to reduce harmonic current of both plant

•Improve transformer efficiency by reducing the temperature

•Avoid nuisance tripping of breakers.

•Implementation result: Reduce Harmonic current level from 23% into 2%

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LED Display Manufacturing Plant

Industry

Asan, South Korea

LED Display Manufacturing plant installed a lot of UPS and facing lots of PQ problem

High harmonic due to UPS and manufacturing equipments

- **Harmonic mitigation**
- **Correction of the P.F.**
- **Meet Korean Regulation**

•High transformer temperature due to harmonic current

•Non-compliance to local harmonics regulations.

•Increase losses

Issues addressed:

- Power loss mitigation
- Comply with Korean regulation of 5% harmonics
- Improved transformer capacity
- Improved power factor

AccuSine+

Success Story:

•Customer wants to mitigate harmonic and improve plant efficiency.

•Customer has 30 units of UPS that causing harmonic problems.

•Installed Accusine PCS 300A x 18 nos to mitigate the harmonics and also improved PF correction.

•Improved power factor from 0.79 to 0.85

•Improved THDv resulting in prevention of misoperation

Cloud Farms for OS Software Customer

Data Centers

USA

100%	**Reactive power compensation**
40°C	**Maximum operational temperature**
<2cycles	**Cycle by cycle continuous adjustment**

- Cloud Farms emerged beginning in 2012
- Site to meet IEEE 519-2014 harmonic standards - new SMPS for servers provide compliance
- Cloud Farms are the future of data processing (sites to increase worldwide)

Issues addressed

- Leading PF due to server SMPS part load mode
- Backup generators faulting (leading VARs too much to handle)
- Utility PF penalties apply (same as lagging penalties)
- Mains current imbalance due to single phase SMPS

AccuSine+

Success Story:

•Simple installation, ease of use solution includes AccuSine PFV – 32x 300A units per 25 MW site)

•Integrates AccuSine PCS+, transformers, and LV switchgear

•Instantaneous reactive power for displacement power factor correction of leading power factors and mains current balancing

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Conclusion

Key Takeaways

IEEE STD 519-2014 and SE Complete Solutions

Major Changes in IEEE STD 519-2014:

- PCC clarification: Between the system owner and user.
- Responsibility: Shared by system owner & user
- References: All reference to IEC61000
- Definitions: THD and TDD up to 50th harmonic order only.
- New instrument compliance: IEC61000-4-7 & IEC61000-4-30
- New Terminologies for Harmonic Measurements:
  - Very short time harmonic measurements: 24 hours (1 day)
  - Short time harmonic measurements: 7-day period (1 week)
- Harmonic Voltage Limits
  - Daily 99th percentile **very short time** (3 s) values should be less than 1.5 times the values given in Table.
  - Weekly 95th percentile **short time** (10 min) values should be less than the values given in Table.
- Current Distortion Limits
  - Daily 99th percentile **very short time** (3 s) values should be less than 2.0 times the values given in the Tables.
  - Weekly 99th percentile **short time** (10 min) values should be less than 1.5 times the values given in Tables.
  - Weekly 95th percentile **short time** (10 min) values should be less than the values given in Tables.

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