IEEE Std 519-2014

Understanding & Mitigating Harmonic Distortion in Data Centers

March 9, 2021

Today's Speakers

Joerg Desler

President of STULZ USA

Joerg Desler is President of STULZ Air Technology Systems, Inc. based in Frederick, Maryland, the US arm of STULZ. Joerg started with STULZ GmbH in Hamburg, Germany in 1992 and relocated to the US in 2001 where he was responsible for manufacturing, engineering and R&D before moving into his current role. Joerg holds an Electrical Engineering degree from the University of Applied Sciences in Hamburg, Germany and is a member of APICS and ASHRAE.

Anthony Hoevenaars, PEng

President & CEO of Mirus International

Anthony joined MIRUS in 1996. Tony is a registered professional engineer and a member of the IEEE. He received his engineering degree in 1979 from the University of Western Ontario in London, Canada. Tony was the first to implement a zero sequence filter (in 1987) to reduce the neutral current at a power panel servicing a high concentration of personal computers at the IBM site. Tony has published and presented numerous technical papers on power quality and harmonics.

Dave Meadows

Director of Technology at STULZ USA

Dave Meadows is the Director of Technology at STULZ USA and has a BS in Mechanical Engineering from the University of Maryland, Baltimore County. Dave is a voting member on multiple ASHRAE committees.

MIRUS is Harmonic Mitigation

MIRUS International provides world-class power quality improvement products for mission critical operations

Our solutions:

- Minimize disruption to the power supply
- Improve reliability
- Adhere to the strictest regulatory requirements
- Save energy and reduce operating costs

Markets include Data Centers, HVAC, Oil & Gas, Marine, Water/Wastewater, Induction Heating/Welding, Industrial and Commercial Facilities

Climate. Customized.

STULZ is a privately owned, global manufacturer of highly efficient temperature and humidity management technology.

STULZ Engineers & Manufactures:

- Air Conditioners
- Air Handlers
- Ultrasonic Humidifiers
- Desiccant Dehumidifiers
- Custom Solutions

Solutions for:

Industrial | Commercial | Secure Mission Critical Applications

AGENDA

- What is IEEE Std 519?
  - Why is TDD used to define Current Distortion Limits?
  - What are the Main Differences between the 2014 version and previous 1992 version?
- What makes IEEE Std 519 difficult to apply and can it be made easier?
- LINEATOR AUHF Wide Spectrum Harmonic Filter
- Analysis for IEEE 519 Compliance of a Hospital HVAC System
- Recommended Harmonic Mitigation Specification
- Summary and Conclusion

Harmonic Standard:

IEEE Std 519 - 2014, Recommended Practices and Requirements for Harmonic Control in Electrical Power Systems

- Defines voltage and current distortion limits at PCC
- Intended to be used as a system standard
- Recognizes responsibility of both User and Utility
- Considers both linear and non-linear loading

Sounds simple enough but why then is it often so difficult to apply?

Let's Start with some Definitions from the Standard

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.

Total Harmonic Distortion (THD)

The ratio of the root mean square of the harmonic current, considering harmonic components up to the 50th order and specifically excluding interharmonics, expressed as a percentage of the fundamental. Harmonic components of order greater than 50 may be included when necessary.

$$iTHD = \frac{\sqrt{I_2^2 + I_3^2 + I_4^2 + I_5^2 + \ldots}}{I_1} \times 100\%$$

$$vTHD = \frac{\sqrt{V_2^2 + V_3^2 + V_4^2 + V_5^2 + \ldots}}{V_1} \times 100\%$$

More Definitions

Total Demand Distortion (TDD)

The ratio of the root mean square of the harmonic current, considering harmonic components up to the 50th order and specifically excluding interharmonics, expressed as a percentage of the maximum demand current. Harmonic components of order greater than 50 may be included when necessary.

$$iTDD = iTHD \times \frac{I_{(meas)}}{I_L}$$

Maximum Demand Current (I_L)

The current value at the PCC taken as the sum of the currents corresponding to the maximum demand during each of the 12 previous months divided by 12.

Short Circuit Ratio (I_{SC}/I_L)

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

Why iTDD Makes Sense

350 HP ASD with and without Harmonic Mitigation

	Current Harmonics (Amps)																	
	RMS		5th		7th		11th		13th		Ithd		Itdd		K-factor		PF	
Load	w/o	With	w/o	With	w/o	With	w/o	With	w/o	With	w/o	With	w/o	With	w/o	With	w/o	With
Full	369	352	110	5.0	37	4.9	19	9.5	25	6.1	36%	4.2%	36%	4.2%	8.9	1.5	0.94	0.98
75%	275	257	83	4.8	35	6.6	16	8.1	17	3.9	37%	5.2%	28%	3.9%	9.3	1.7	0.94	1.00
50%	188	171	67	3.5	27	5.7	5.6	5.6	14	3.9	44%	6.1%	22%	3.0%	10	2.2	0.92	1.00
30%	123	108	48	2.8	27	5.9	4.1	3.3	9.2	1.8	55%	7.8%	16%	2.4%	17	2.4	0.88	0.96
25%	109	92	55	2.4	34	5.8	5.3	2.7	7.3	1.8	77%	8.7%	19%	2.2%	17	2.6	0.79	0.93

- iTHD provides a relative measure of the harmonic current content at the measured load level
  - Almost certainly will be higher at lighter load levels than at heavier loading
  - But its the ampere value of current harmonics that contributes to overheating and voltage distortion
- iTDD adjusts for this by factoring in the ratio of actual load to peak load

IEEE Std 519 – 2014 Voltage Distortion Limits

Table 1

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]

- Major change is that for systems < 1.0 kV, vTHD is allowed to be as high as 8.0%
- Also, lower voltage distortion limits for Special Applications and higher limits for Dedicated Systems have been removed

IEEE Std 519 – 2014 Current Distortion Limits – 120V through 69kV

Table 2

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

- Essentially no change from 1992 edition

Main Differences between 2014 and 1992 Editions of IEEE 519

- THD and TDD definitions now allow the inclusion of harmonics above the 50^{th} when necessary.
- Voltage distortion limits for < 1kV systems have been relaxed to 8% from 5%.
- Lower voltage distortion limits for Special Applications and higher limits for Dedicated Systems have been removed.
- Current distortion limits for > 161kV systems have been changed. Current limits for other voltage systems remain the same.
- Very Short Time and Short Time limits have been introduced.
- An allowance for increased harmonic limits at higher frequencies can be applied when steps are taken to reduce lower frequency harmonics.

Section 5.5, Recommendation for Increasing Harmonic Current Limits

It is recommended that the values given in Tables 2, 3 and 4 be increased by a multiplying factor when actions are taken by a user to reduce lower-order harmonics.

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
↓	↓

- The committee must have assumed that by reducing lower frequency harmonics, higher levels of high frequency harmonics would no longer be a problem. But this lacks common sense.
- Higher frequency harmonics will always have a bigger negative effect on a power system so relaxing these limits is not wise.

What Makes IEEE 519 Difficult to Apply

- Often requires an extensive computer simulation which few design engineers, equipment suppliers or contractors can perform
- Accurate analysis requires a detailed 1-Line including load types, cable sizes and cable run lengths
- A PCC location must be agreed upon between the utility, design engineer and end user
- Load profiles and worse case operating conditions need determining
- Peak demand load, I_L, cannot be established at the design stage because it requires operating for at least 1 year
  - I_L is also needed to calculate SCR to establish the applicable harmonic current limits and iTDD in order to determine if these limits are being met

Is There a Better Way?

- What if the limits are applied at the equipment terminals?
  - Equipment manufacturers could then select harmonic mitigation suitable for meeting the specified limits
- What if 'maximum operating current' was used to define max load rather than the standard's definition for peak demand current
  - This value could then be determined at the design stage
- Ensure that iTDD is used and not iTHD
  - This is what the standard intended and for good reason
  - An iTHD value specified over the entire operating range requires excessive mitigation, increasing cost and possibly leading to operational problems
- Select a value of iTDD that best protects the client's interests while complying with the standard

What Can be Used to Ensure Harmonic Compliance with Air Handlers?

LINEATOR AUHF

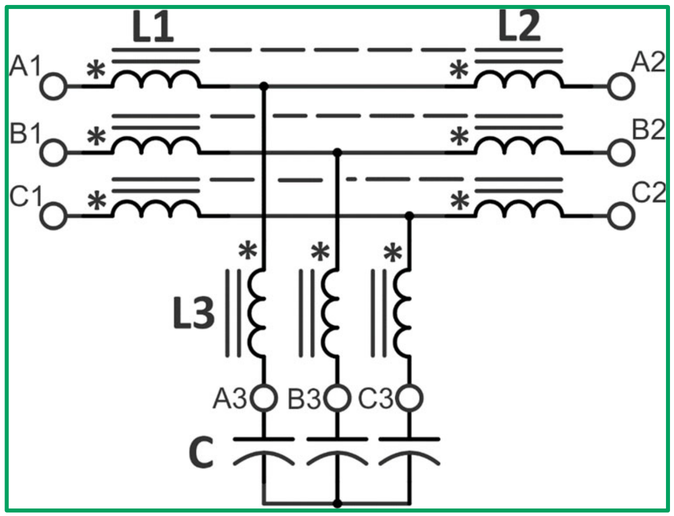
- Series connected, passive harmonic filter for Adjustable Speed Drives and EC Fans
- Better than 18-pulse or AFE performance with 6-pulse ASD
- ‘Real-World Performance Guarantee’
- Meets IEEE and IEC harmonic limits
- Near unity power factor
- Generator compatible
- Highest efficiency which maintains energy savings of today’s air handlers

LINEATOR AUHF

Multiple windings on a common core

High impedance L1 winding

Compensating winding L2 improves performance without increasing voltage drop



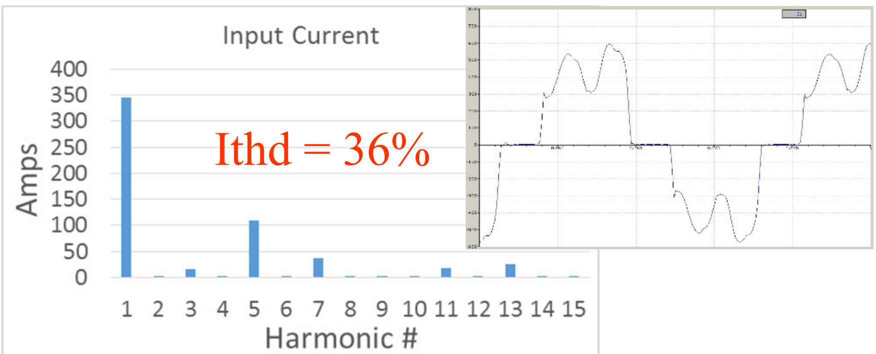
Input tuned below 5th to prevent importation of upstream harmonics

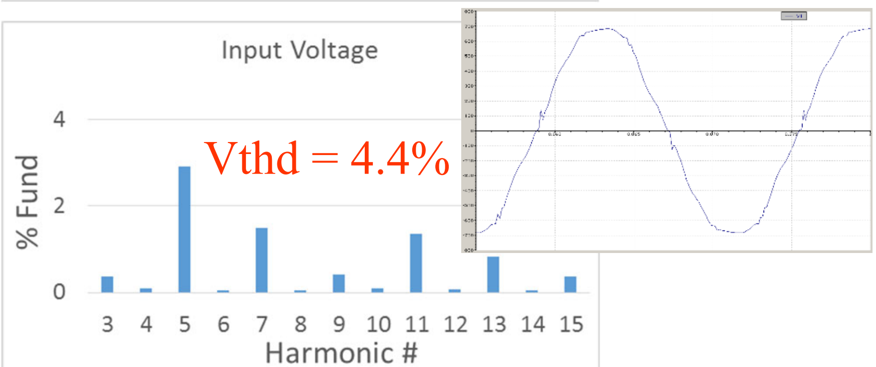
Output tuned above 5th to remove load side harmonics

Unique reactor design allows for smaller cap bank to reduce voltage boost and reactive power at no load

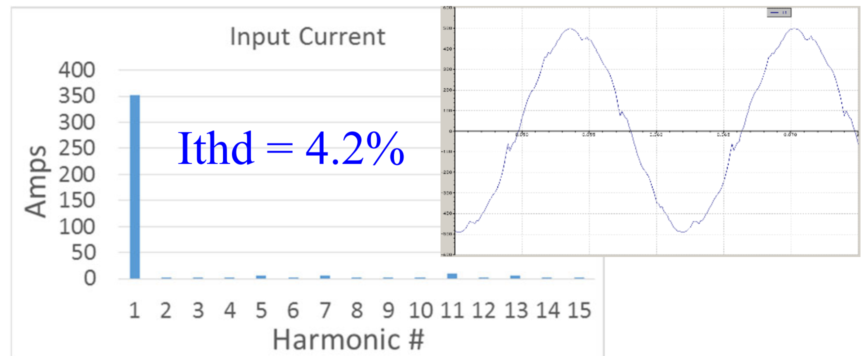
350 HP LINEATOR AUHF-HP

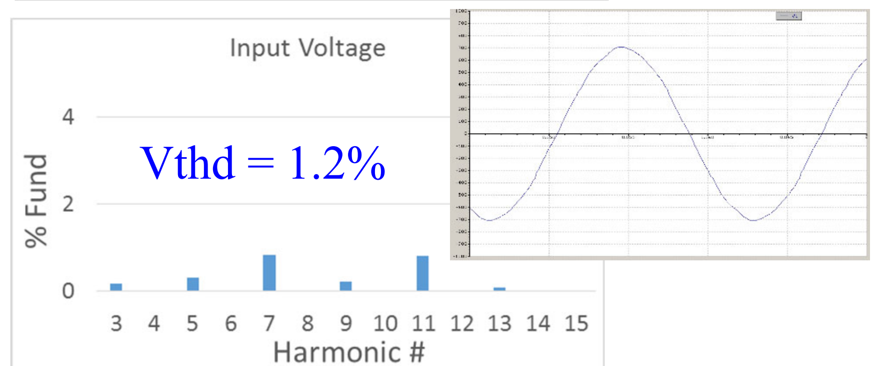
With Reactor





With AUHF-HP





Analysis for IEEE Std 519 Compliance of a Hospital HVAC System

Utility Supply

- 2 x 2500 kVA, 13.8kV to 480V, 5.75% impedance transformers sharing load on 2 buses
- Utility Fault Level: 13.1kA @ 13.8kV

Generator Supply

- 2 x 2000 kW, 480V, Xd" = 13%, PF = 0.8 generators sharing load on 2 buses during emergency conditions

Analysis for IEEE Std 519 Compliance of a Hospital HVAC System

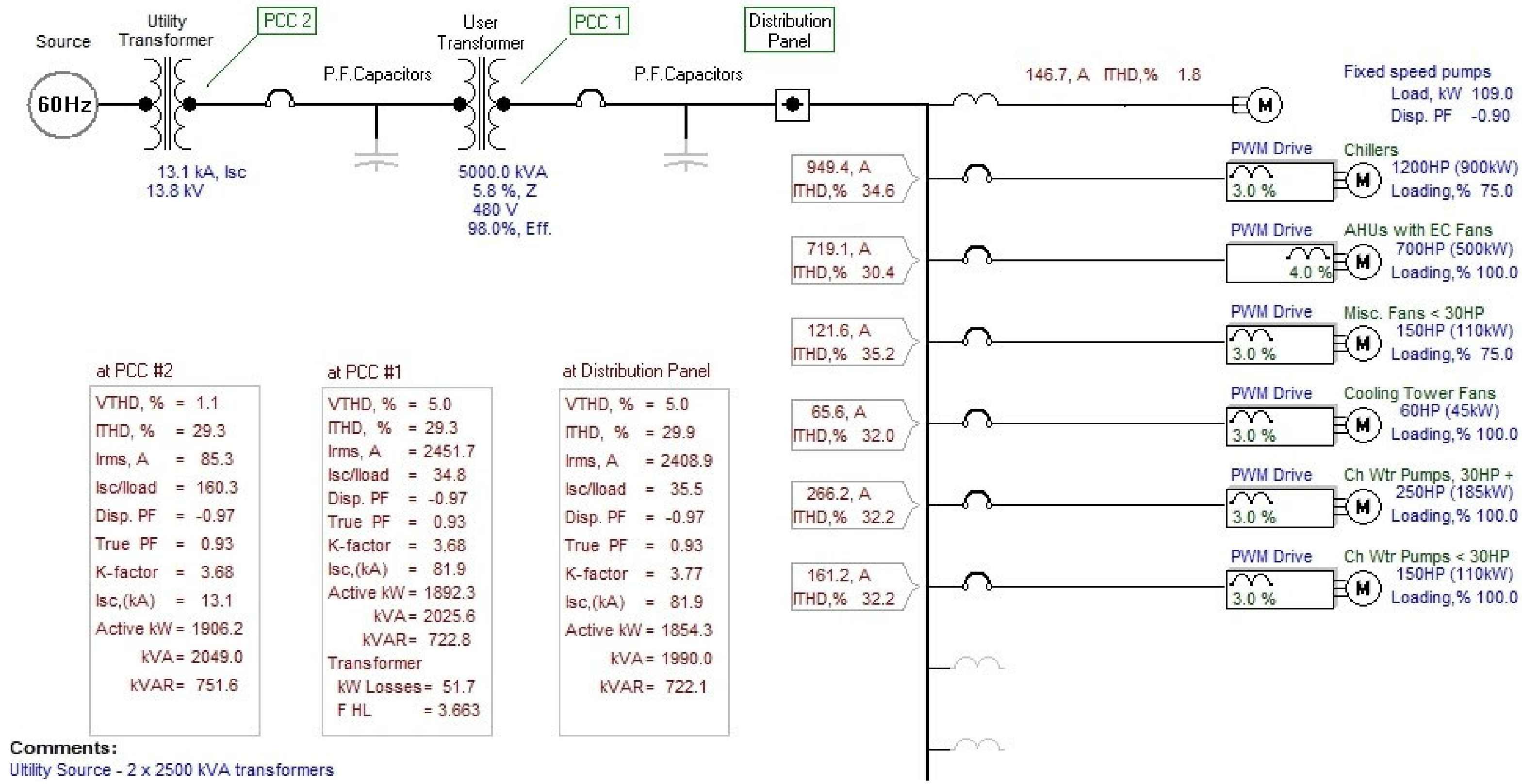
Non-linear load HVAC Equipment

- 3 x 400 HP Chillers with maximum operating load of 75% when redundancy was taken into consideration
- 700 HP total Air Handling Unit load with EC fans
- 4 x 15 HP Cooling Tower fans
- Chilled Water and other pumps
  - Total of 250 HP in sizes 30 HP and larger
  - Total of 150 HP in sizes 25 HP and smaller
- Total of 150 HP of miscellaneous fans 20 HP and smaller

Linear Load

- Multiple fixed speed motors totaling 146 HP (109 kW) with 0.9 PF assumed

Computer Simulation – Utility Supply (Reactors Only)



Computer Simulation – Utility Supply (Reactors Only)

- Exceeds current distortion limits at both Utility Supply (PCC2) and User Transformer (PCC1)
- Meets 2014 voltage distortion limits at PCC2 & PCC1 but exceeds 1992 limits at PCC1

Project Name: Boston Area Hospital
Point of Coupling: PCC #2
Bus voltage at PCC: 13 kV
Short-circuit ratio: 160.3

Summary of Compliance with IEEE Std 519:1992 and IEEE Std 519:2014 Harmonic Limits:

		Calculated Value, [%]	IEEE-519:1992 Limit, [%]		IEEE-519:2014 Limit, [%]	
Voltage Total Harmonic Distortion	(VTHD)	1.1	5.0	PASS	5.0	PASS
Max.Individual Voltage Harmonic		0.9 {5}	3.0	PASS	3.0	PASS
Current Total Demand Distortion	(iTDD)	29.3	15.0	FAIL	15.0	FAIL
Max.Individual current harmonic	<11	27.2 {5}	12.0	FAIL	12.0	FAIL
	11 to 16	5.5 {11}	5.5	FAIL	5.5	FAIL
	17 to 22	1.9 {17}	5.0	PASS	5.0	PASS
	23 to 34	0.7 {25}	2.0	PASS	2.0	PASS
	>35	0.1 {47}	1.0	PASS	1.0	PASS

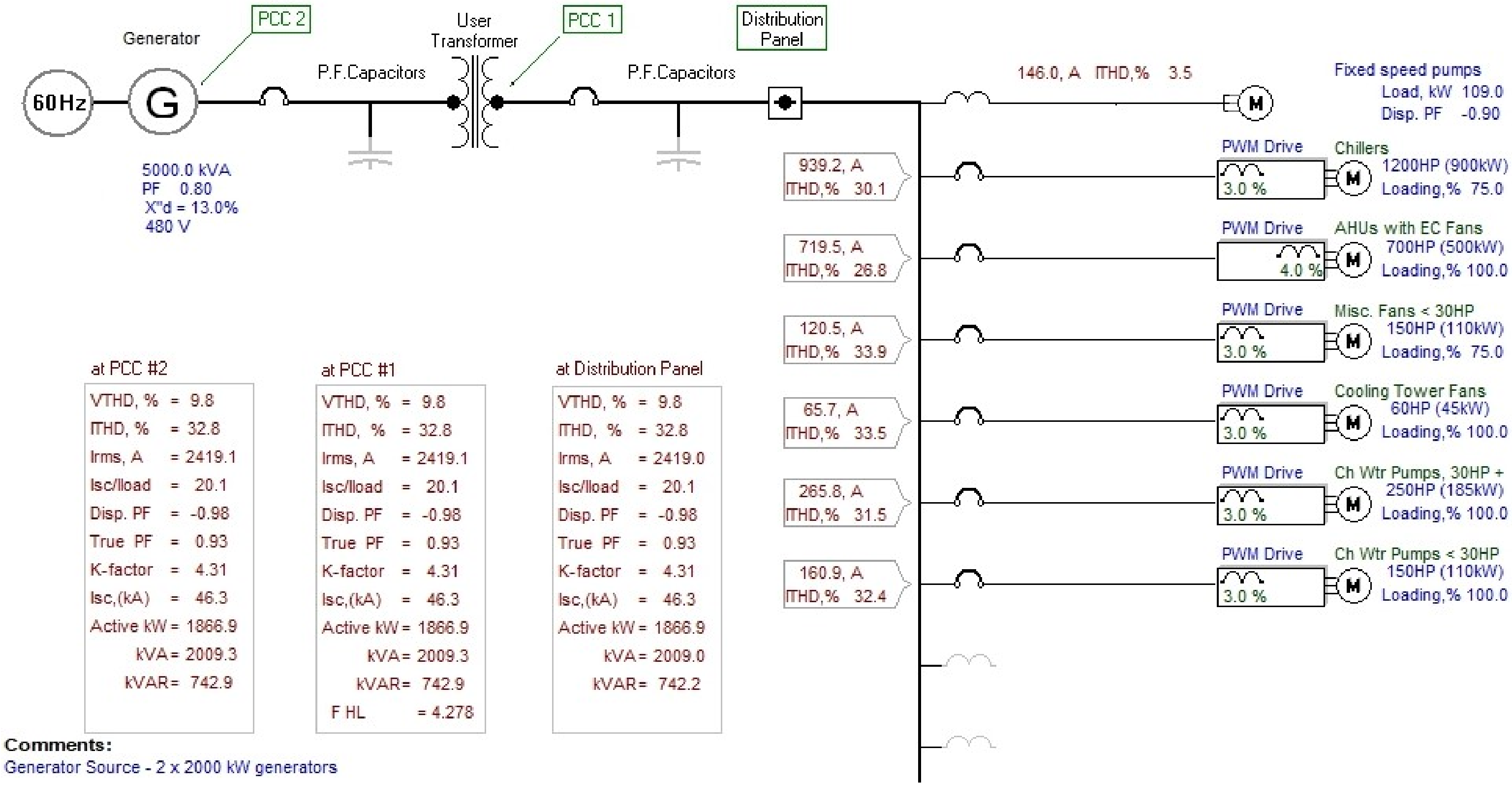
Point of Coupling: PCC #1
Bus voltage at PCC: 480 V
Short-circuit ratio: 34.8

Summary of Compliance with IEEE Std 519:1992 and IEEE Std 519:2014 Harmonic Limits:

		Calculated Value, [%]	IEEE-519:1992 Limit, [%]		IEEE-519:2014 Limit, [%]	
Voltage Total Harmonic Distortion	(VTHD)	5.0	5.0	FAIL	8.0	PASS
Max.Individual Voltage Harmonic		4.0 {5}	3.0	FAIL	5.0	PASS
Current Total Demand Distortion	(iTDD)	29.3	8.0	FAIL	8.0	FAIL
Max.Individual current harmonic	<11	27.2 {5}	7.0	FAIL	7.0	FAIL
	11 to 16	5.5 {11}	3.5	FAIL	3.5	FAIL
	17 to 22	1.9 {17}	2.5	PASS	2.5	PASS
	23 to 34	0.7 {25}	1.0	PASS	1.0	PASS
	>35	0.1 {47}	0.5	PASS	0.5	PASS

Notes: Based on the information provided, this application will NOT meet IEEE Std 519 harmonic limits

Computer Simulation – Generator Supply (Reactors Only)



	at PCC #2	at PCC #1	at Distribution Panel
VTHD, %	9.8	9.8	9.8
ITHD, %	32.8	32.8	32.8
Irms, A	2419.1	2419.1	2419.0
Isc/Iload	20.1	20.1	20.1
Disp. PF	-0.98	-0.98	-0.98
True PF	0.93	0.93	0.93
K-factor	4.31	4.31	4.31
Isc,(kA)	46.3	46.3	46.3
Active kW	1866.9	1866.9	1866.9
kVA	2009.3	2009.3	2009.0
kVAR	742.9	742.9	742.2
F HL		4.278	

Comments:
Generator Source - 2 x 2000 kW generators

Computer Simulation – Generator Supply (Reactors Only)

- Exceeds current distortion limits at both Utility Supply (PCC2) and User Transformer (PCC1)
- Exceeds both 2014 and 1992 voltage distortion limits at PCC2 & PCC1

Project Name: Boston Area Hospital
Point of Coupling: PCC #2
Bus voltage at PCC: 480 V
Short-circuit ratio: 20.1

Summary of Compliance with IEEE Std 519:1992 and IEEE Std 519:2014 Harmonic Limits:

		Calculated Value, [%]	IEEE-519:1992 Limit, [%]		IEEE-519:2014 Limit, [%]	
Voltage Total Harmonic Distortion	(VTHD)	9.8	5.0	FAIL	8.0	FAIL
Max.Individual Voltage Harmonic		7.6 { 5}	3.0	FAIL	5.0	FAIL
Current Total Demand Distortion	(iTDD)	32.8	8.0	FAIL	8.0	FAIL
Max.Individual current harmonic	<11	30.2 { 5}	7.0	FAIL	7.0	FAIL
	11 to 16	6.0 {11}	3.5	FAIL	3.5	FAIL
	17 to 22	2.1 {17}	2.5	PASS	2.5	PASS
	23 to 34	0.8 {25}	1.0	PASS	1.0	PASS
	>35	0.2 {41}	0.5	PASS	0.5	PASS

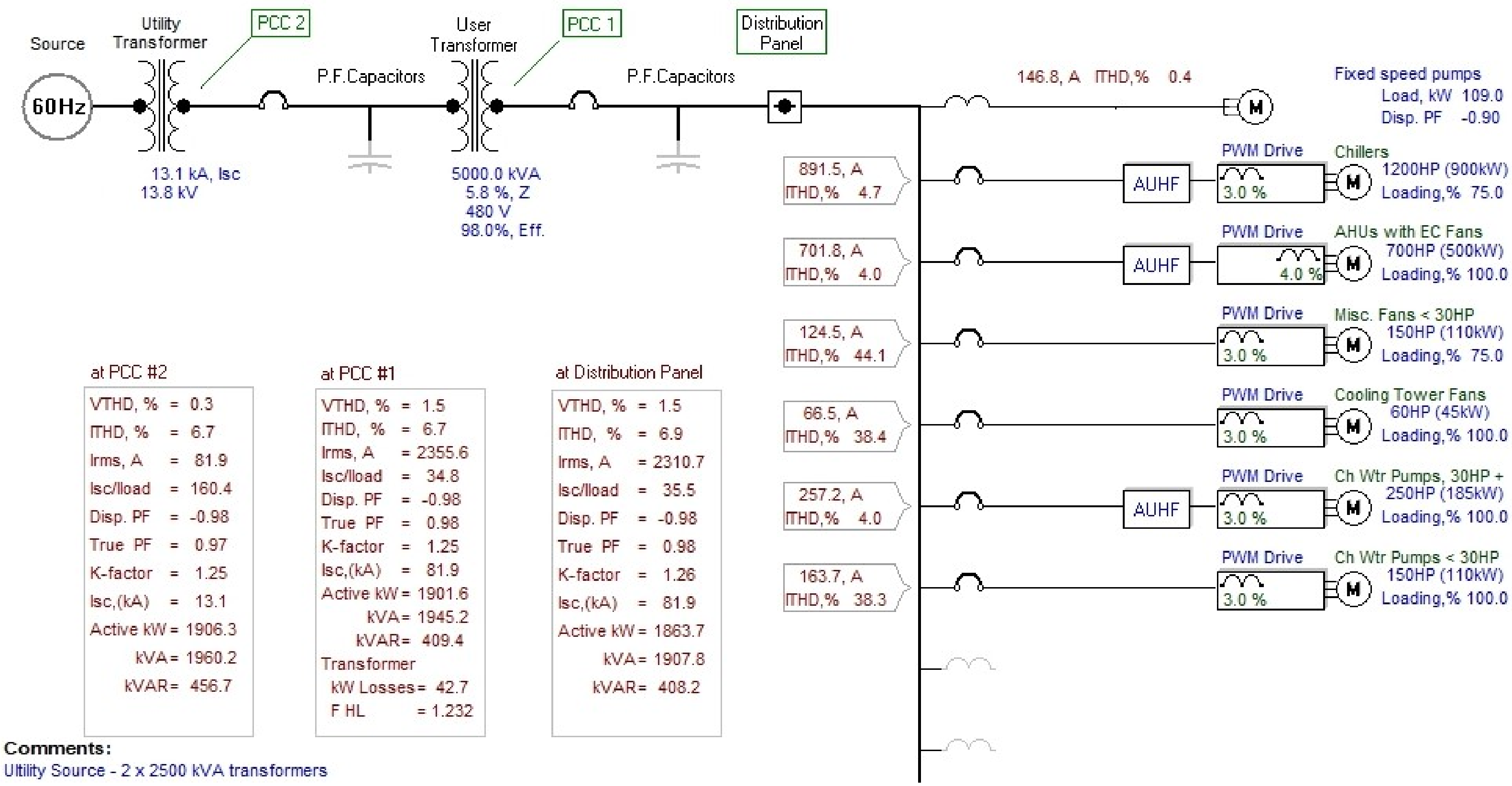
Point of Coupling: PCC #1
Bus voltage at PCC: 480 V
Short-circuit ratio: 20.1

Summary of Compliance with IEEE Std 519:1992 and IEEE Std 519:2014 Harmonic Limits:

		Calculated Value, [%]	IEEE-519:1992 Limit, [%]		IEEE-519:2014 Limit, [%]	
Voltage Total Harmonic Distortion	(VTHD)	9.8	5.0	FAIL	8.0	FAIL
Max.Individual Voltage Harmonic		7.6 { 5}	3.0	FAIL	5.0	FAIL
Current Total Demand Distortion	(iTDD)	32.8	8.0	FAIL	8.0	FAIL
Max.Individual current harmonic	<11	30.2 { 5}	7.0	FAIL	7.0	FAIL
	11 to 16	6.0 {11}	3.5	FAIL	3.5	FAIL
	17 to 22	2.1 {17}	2.5	PASS	2.5	PASS
	23 to 34	0.8 {25}	1.0	PASS	1.0	PASS
	>35	0.2 {41}	0.5	PASS	0.5	PASS

Notes: Based on the information provided, this application will NOT meet IEEE Std 519 harmonic limits

Computer Simulation – Utility Supply (With Harmonic Mitigation)



Computer Simulation – Utility Supply (With Harmonic Mitigation)

- Meets current distortion limits at both Utility Supply (PCC2) and User Transformer (PCC1)
- Meets both 2014 and 1992 voltage distortion limits at PCC2 & PCC1

Project Name: Boston Area Hospital
Point of Coupling: PCC #2
Bus voltage at PCC: 13 kV
Short-circuit ratio: 160.4

Summary of Compliance with IEEE Std 519:1992 and IEEE Std 519:2014 Harmonic Limits:

		Calculated Value, [%]	IEEE-519:1992 Limit, [%]		IEEE-519:2014 Limit, [%]	
Voltage Total Harmonic Distortion	(VTHD)	0.3	5.0	PASS	5.0	PASS
Max.Individual Voltage Harmonic		0.2 {11}	3.0	PASS	3.0	PASS
Current Total Demand Distortion	(iTDD)	6.7	15.0	PASS	15.0	PASS
Max.Individual current harmonic	<11	4.8 { 5}	12.0	PASS	12.0	PASS
	11 to 16	2.5 {11}	5.5	PASS	5.5	PASS
	17 to 22	0.6 {17}	5.0	PASS	5.0	PASS
	23 to 34	0.1 {29}	2.0	PASS	2.0	PASS
	>35	0.1 {37}	1.0	PASS	1.0	PASS

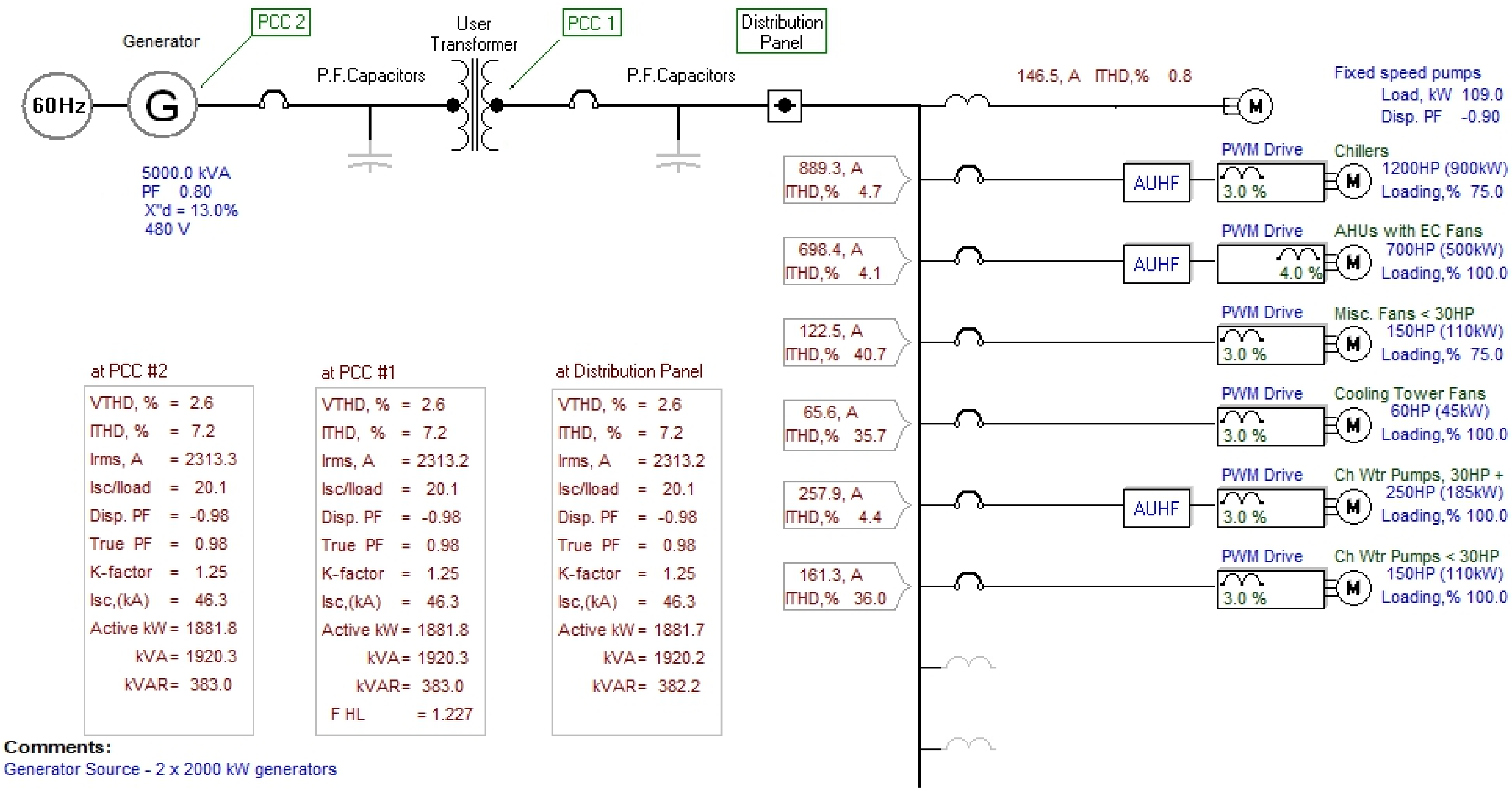
Point of Coupling: PCC #1
Bus voltage at PCC: 480 V
Short-circuit ratio: 34.8

Summary of Compliance with IEEE Std 519:1992 and IEEE Std 519:2014 Harmonic Limits:

		Calculated Value, [%]	IEEE-519:1992 Limit, [%]		IEEE-519:2014 Limit, [%]	
Voltage Total Harmonic Distortion	(VTHD)	1.5	5.0	PASS	8.0	PASS
Max.Individual Voltage Harmonic		0.8 {11}	3.0	PASS	5.0	PASS
Current Total Demand Distortion	(iTDD)	6.7	8.0	PASS	8.0	PASS
Max.Individual current harmonic	<11	4.8 { 5}	7.0	PASS	7.0	PASS
	11 to 16	2.5 {11}	3.5	PASS	3.5	PASS
	17 to 22	0.6 {17}	2.5	PASS	2.5	PASS
	23 to 34	0.1 {29}	1.0	PASS	1.0	PASS
	>35	0.1 {37}	0.5	PASS	0.5	PASS

Notes: Based on the information provided, this application will meet IEEE Std 519 harmonic limits

Computer Simulation – Generator Supply (With Harmonic Mitigation)



at PCC #2

VTHD, %	= 2.6
ITHD, %	= 7.2
Irms, A	= 2313.3
Isc/Iload	= 20.1
Disp. PF	= -0.98
True PF	= 0.98
K-factor	= 1.25
Isc,(kA)	= 46.3
Active kW	= 1881.8
kVA	= 1920.3
kVAR	= 383.0

at PCC #1

VTHD, %	= 2.6
ITHD, %	= 7.2
Irms, A	= 2313.2
Isc/Iload	= 20.1
Disp. PF	= -0.98
True PF	= 0.98
K-factor	= 1.25
Isc,(kA)	= 46.3
Active kW	= 1881.8
kVA	= 1920.3
kVAR	= 383.0
F HL	= 1.227

at Distribution Panel

VTHD, %	= 2.6
ITHD, %	= 7.2
Irms, A	= 2313.2
Isc/Iload	= 20.1
Disp. PF	= -0.98
True PF	= 0.98
K-factor	= 1.25
Isc,(kA)	= 46.3
Active kW	= 1881.7
kVA	= 1920.2
kVAR	= 382.2

Comments:
Generator Source - 2 x 2000 kW generators

Computer Simulation – Generator Supply (With Harmonic Mitigation)

- Meets current distortion limits at Generator terminals (PCC2) and (PCC1)
- Meets both 2014 and 1992 voltage distortion limits at Generator terminals

Project Name: Boston Area Hospital
Point of Coupling: PCC #2
Bus voltage at PCC: 480 V
Short-circuit ratio: 20.1

Summary of Compliance with IEEE Std 519:1992 and IEEE Std 519:2014 Harmonic Limits:

		Calculated Value, [%]	IEEE-519:1992 Limit, [%]		IEEE-519:2014 Limit, [%]	
Voltage Total Harmonic Distortion	(VTHD)	2.6	5.0	PASS	8.0	PASS
Max.Individual Voltage Harmonic		1.4 {7}	3.0	PASS	5.0	PASS
Current Total Demand Distortion	(iTDD)	7.2	8.0	PASS	8.0	PASS
Max.Individual current harmonic	<11	5.5 {5}	7.0	PASS	7.0	PASS
	11 to 16	2.2 {11}	3.5	PASS	3.5	PASS
	17 to 22	0.3 {19}	2.5	PASS	2.5	PASS
	23 to 34	0.3 {29}	1.0	PASS	1.0	PASS
	>35	0.2 {35}	0.5	PASS	0.5	PASS

Point of Coupling: PCC #1
Bus voltage at PCC: 480 V
Short-circuit ratio: 20.1

Summary of Compliance with IEEE Std 519:1992 and IEEE Std 519:2014 Harmonic Limits:

		Calculated Value, [%]	IEEE-519:1992 Limit, [%]		IEEE-519:2014 Limit, [%]	
Voltage Total Harmonic Distortion	(VTHD)	2.6	5.0	PASS	8.0	PASS
Max.Individual Voltage Harmonic		1.4 {7}	3.0	PASS	5.0	PASS
Current Total Demand Distortion	(iTDD)	7.2	8.0	PASS	8.0	PASS
Max.Individual current harmonic	<11	5.5 {5}	7.0	PASS	7.0	PASS
	11 to 16	2.2 {11}	3.5	PASS	3.5	PASS
	17 to 22	0.3 {19}	2.5	PASS	2.5	PASS
	23 to 34	0.3 {29}	1.0	PASS	1.0	PASS
	>35	0.2 {35}	0.5	PASS	0.5	PASS

Notes: Based on the information provided, this application will meet IEEE Std 519 harmonic limits

Recommended Specification for IEEE Std 519 Compliance

Each Adjustable Speed Drive of 30 HP and larger shall be supplied with a passive harmonic filter to meet all requirements outlined in IEEE Std 519 (both 1992 and 2014 editions) for individual and total harmonic voltage and current distortion. The Point of Common Coupling (PCC) for all voltage and current harmonic calculations and measurements shall be the input terminals to the harmonic mitigation equipment.

- Harmonic mitigation shall be by passive inductor/capacitor network. To prevent possibility of switching frequency resonance, active electronic components shall not be used.
- Performance Guarantee: iTDD must be <8% with background voltage distortion up to 5% and voltage imbalance up to 3%. [Or for more critical applications, iTDD must be <5% with background voltage distortion up to 2% and voltage imbalance up to 2%]. The filter must be capable of operating in voltage distortion environments up to 8% without derating.

Recommended Specification for IEEE Std 519 Compliance (cont)

- Power factor shall be > 0.95 in operating range from 25% to full load.

- To ensure compatibility with engine generators, the harmonic mitigation equipment must never introduce a capacitive reactive power (kVAR) which is greater than 15% of its kW rating for sizes ≥ 100HP and 20% for sizes ≤ 75HP. If the filter does not meet this requirement, it must integrate a capacitor switching contactor.

- Factory Performance Testing: Manufacturer must be capable of factory testing for harmonic mitigating performance and energy efficiency under actual adjustable speed drive loads.

Summary and Conclusion

- IEEE Std 519 has become the accepted standard for addressing harmonics in N. America and many other areas around the world

- Applying it as a system standard can be challenging however since,
  - Determining the peak demand current at the design stage requires load measurements for at least 1 year which, obviously can't be done
  - Accumulating the distribution and load information required to do a proper computer simulation can be onerous
  - It requires a computer simulation program with accurate models of loads and distribution equipment and the ability to handle complex 1-Lines

Summary and Conclusion (cont.)

- To address this, many engineers have adopted the approach of applying the standard's harmonic limits at the non-linear load equipment terminals with,
  - An understanding that a load's maximum operating current can be a good measure of the peak demand load and
  - Targeted limits should be based on iTDD, as defined in the standard, and not iTHD

- The use of wide spectrum passive harmonic filters can be very effective in meeting harmonic limits when ASD and EC fans are used
  - iTDD levels of < 8% and < 5% can be easily and reliably met using these devices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