Revisions to IEEE-519

Robert E. Fuhr, P.E.

PowerStudies INC.®

1

What are Harmonics?

- A harmonic is a component frequency of a harmonic motion of an electromagnetic wave that is an integral Multiply of the fundamental frequency. (Webster's Dictionary)
- Key words are
  - "**Fundamental Frequency**"
  - "**Multiply**"

2

What are Harmonics?

- It is a mathematical way to break down a non sinusoidal repeating waveforms (Fourier Analysis)
- The total waveform is the sum of multiple sine waves that have different frequencies from the fundamental (60 Hz)

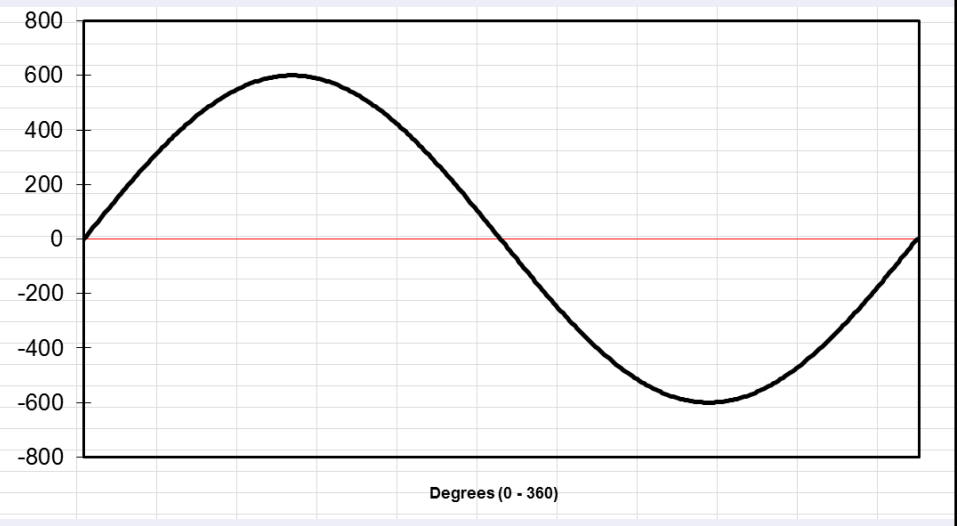
3

What are Harmonics?

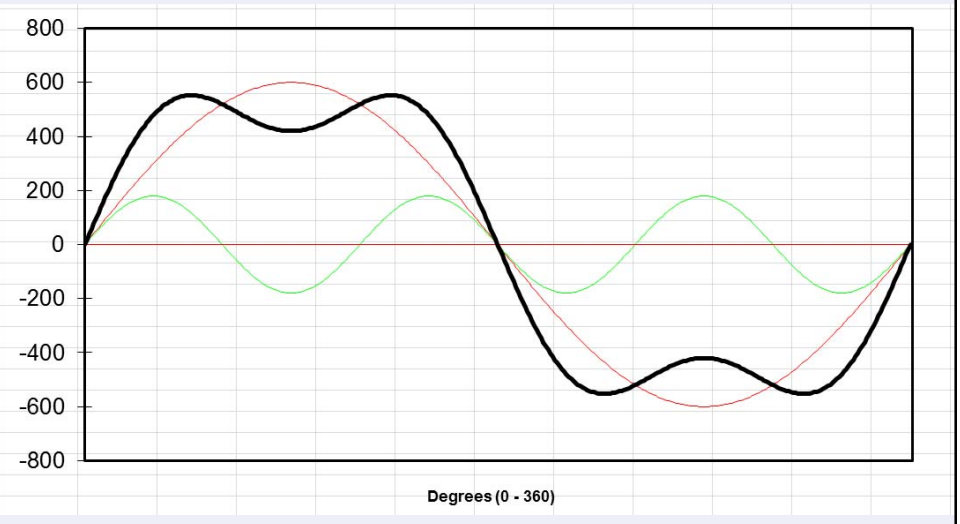
- In the US, the fundamental frequency is **60 Hz**
- Integral Multiply means multiplying the fundamental frequency by a whole number(i.e. 2, 3, 4, ...etc.)
- 3rd Harmonic is 3 X 60 Hz = 180 Hz

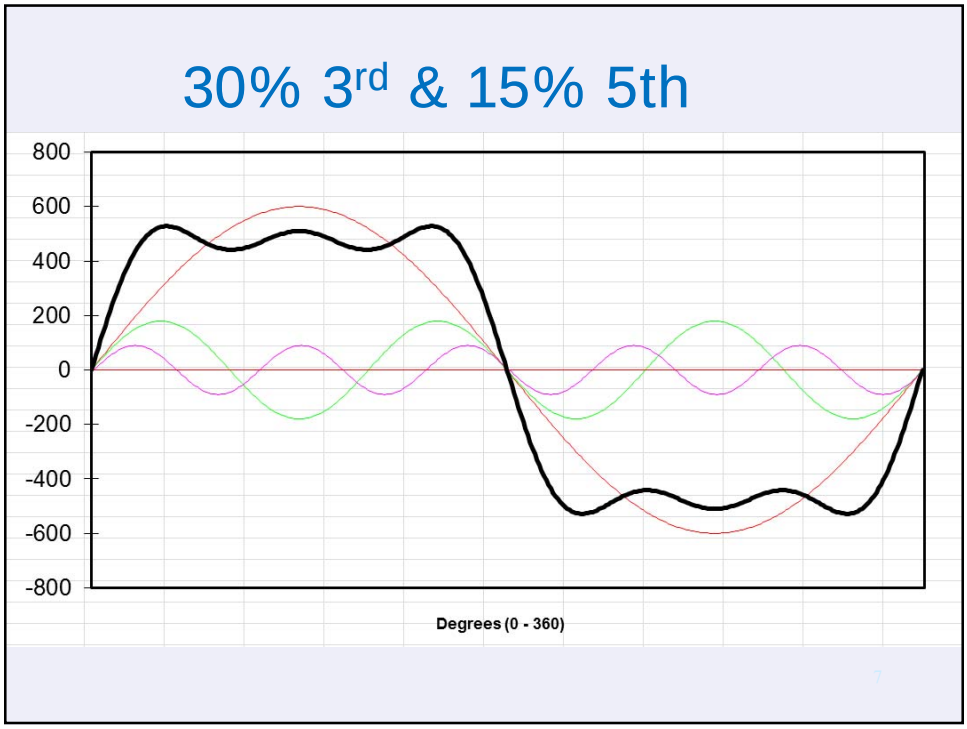
4

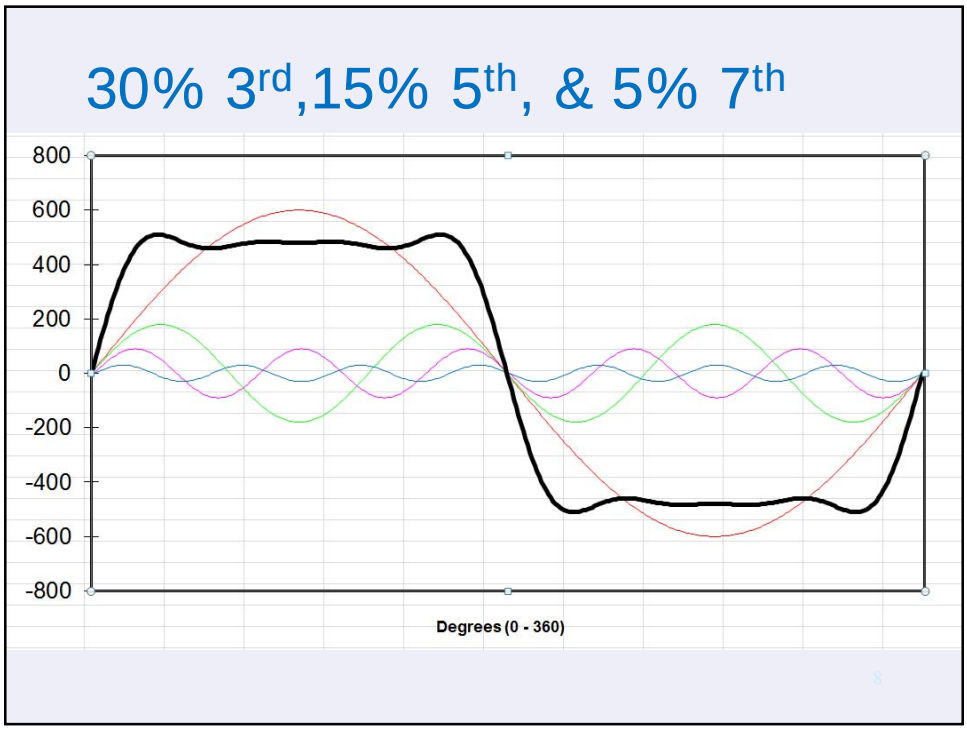
60 Hz Wave – No Harmonics



30% 3rd




30% 3rd & 15% 5th
800
600
400
200
0
-200
-400
-600
-800
Degrees (0 - 360)


30% 3rd,15% 5th, & 5% 7th
800
600
400
200
0
-200
-400
-600
-800
Degrees (0 - 360)

Sources of Harmonics

- Solid State Variable Speed Drives
- Arc Furnaces
- Rectifiers (AC-DC Converters)
- Solid State electronic devices which contains a poor power supply
  - computers, TVs, laser printers, copy machines…
- Solid State UPS units

9

Sources of Harmonics

- Welding Units
- Solid State Fluorescent & LED Lighting Ballast
- Usually a problem for Industrial Facilities
  - Heavy users of VSDs

10

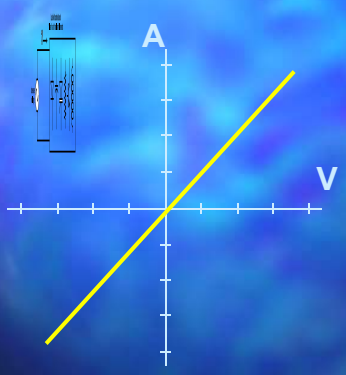
What Causes Harmonics?

Answer: Non-linear loads.

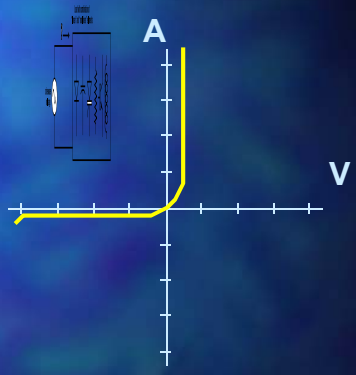
There are two types of loads: **Linear** and **Non-linear.**

11

Impedance Characteristics for Linear and Non-linear Devices



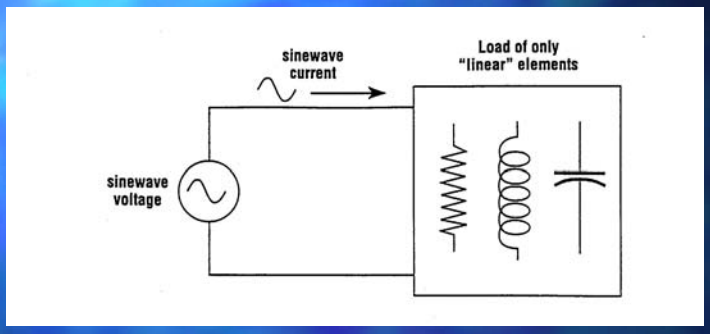
Volt-Amps graph for a linear device



Volt-Amps graph for a non-linear device

12

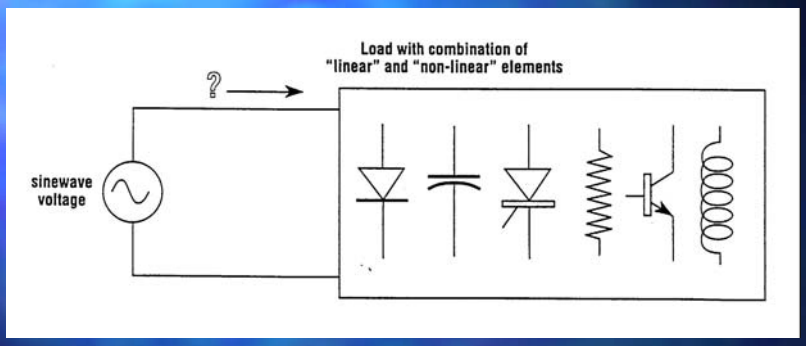
Linear Load



When a sine-wave voltage is connected to a load of linear elements, the current will always be a sine-wave of the same frequency.

13

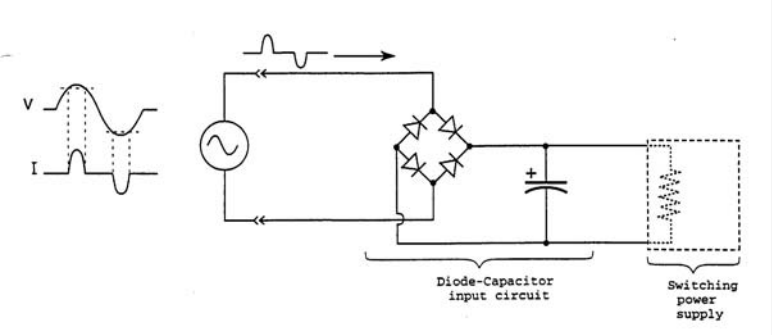
Non-Linear Load



When the load contains a combination of linear and non-linear elements, the current can be distorted containing harmonics of higher frequencies.

14

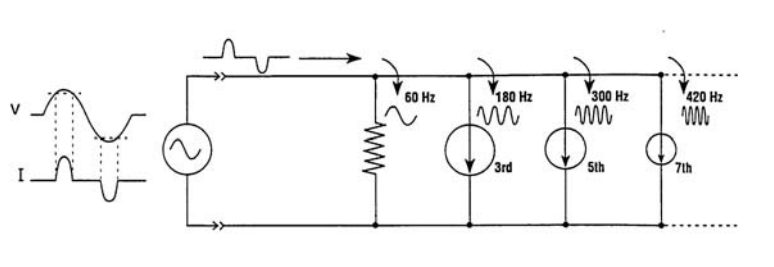
A Typical Non-Linear Load



The diode -capacitor input circuit draws short pulses of line current during the peak of the line voltage.

15

Electrical Equivalent Circuit



The load can be represented by a resistor in parallel with several current generators operating at harmonic frequencies.

16

Effects of Harmonics

- Overheated Transformers
- Heating Of Motors
- Abnormal skin effect heating on conductors.
- Heating Of Neutral Conductors
- Low Voltage At End Loads
- High Neutral To Ground Voltages At End Loads

17

Effects of Harmonics

- Distorted Voltage
- Communication Problems
- Capacitor Bank Application Problems
- Unreliable Operation Of Electronic Equipment
- Control Of Speed And Voltage Problems On Emergency Generators
- Current Measurement Problems

18

Effects of Harmonics

- Operation Problems Of Relays And Circuit Breakers

19

IEEE – 519 Recommended Practice and Requirements for Harmonic Control in Electric Power Systems

20

IEEE – 519 – What is it?

- It is a “Recommended Practice”, not a “Standard”.
- It is a “system” practice, not an “equipment” practice.
- Addresses the steady state condition.
- Only addresses harmonic limits at PCC, not within the facility.
- Harmonic Current Limits For Utility Customers`

21

IEEE-519 - Philosophy of the Standard

- The customer is responsible for limiting the amount of harmonic current injected back into the overall power system.
- The utility is responsible for avoiding resonance conditions on the power system
  - causes unacceptable distortion levels.

22

IEEE-519 - Philosophy of the Standard

- Basically, the utility promises a voltage quality.

23

IEEE – 519 - PCC

- Harmonic current limits are measured at the point of common coupling (PCC) between the utility and the customer.
- PCC: A point on a public power supply system where it connects to the customer.
  - Usually where the utility meter is connected.

24

IEEE – 519 I_L

- Maximum Demand Load Current, I_L: established at PCC and should be taken as the sum of the current corresponding to the maximum demand during each of the twelve previous months divided by 12.
- I_L = maximum demand load current at PCC under **normal** load operating conditions.

25

IEEE – 519 Isc

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

26

IEEE – 519 - THD%

- THD (total harmonic distortion): ratio of the root mean square of the harmonic content,
  - Uses harmonic components up to the 50th order
  - Excludes interharmonics
  - Expressed as a percent of the fundamental
  - Typical PQ meter measurement

27

IEEE – 519 - TDD%

- TDD (total demand distortion): ratio of the root mean square of the harmonic content.
  - Uses harmonic components up to the 50th order
  - Excludes interharmonics.
  - Expressed as a percent of maximum demand current.
  - Most PQ Meters do not measure TDD%.

28

IEEE – 519 – THD & TDD

- THD and TDD are not the same!
- TDD prevents a user from being penalized for harmonics during periods of light loading.
- Chapter 4 contains new info regarding harmonic measurements – instruments must comply with IEC 61000-4-7 and IEC 61000-4-30

29

IEEE-519 Voltage Distortion Limits

- At the PCC, system owners or operators (Utilities) 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.

30

IEEE-519 Voltage Distortion Limits

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.

31

IEEE – 519 Current Limits

- Harmonic Current Limits For Utility Customers
- Harmonic current limits are measured at the point of common coupling (PCC) between the utility and the customer.

32

IEEE-519 Current Distortion Limits - 120 V to 69 kV

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

33

IEEE-519 Current Distortion Limits - 69 kV to 161 kV

Table 3—Current distortion limits for systems rated above 69 kV through 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
< 20[c]	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

34

IEEE-519 Current Distortion Limits - >161 kV

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

35

IEEE-519 Current Distortion Limits -

- At the PCC, users should limit harmonic currents shown in the (3) Limit Tables.

36

IEEE-519 - Current Distortion Limits

- Daily 99th percentile very short time (3 s) harmonic currents should be less than 2.0 times the values given in Table 2.
- Weekly 99th percentile short time (10 min) harmonic currents should be less than 1.5 times the values given in Table 2.
- Weekly 95th percentile short time (10 min) harmonic currents should be less than the values given in Table 2.

37

IEEE-519 - Harmonics – How to Reduce Them

- Filters
  - Passive (Tuned Filters)
  - Active (Fast Switching Harmonic Canceling)
- Higher Pulse Drives (12, 18 vs 6 Pulse)
- Phase Shifting Transformers
- Specify higher quality power supplies for computers, PLCs and other electronic equipment.

38

Key Points to Remember!!!

- Non-linear loads create harmonics.
- Harmonics create abnormal skin effect heating on conductors.
- Capacitors and harmonics (non-linear loads) do not mix!!!!
- IEEE-519 Standard is to be applied at the PCC, not downstream equipment (i.e. MCCs, Panelboards, VSDs)

39

Key Points to Remember!!!

- Incorrect to specify equipment that must meet IEEE 519 Standard.

40

For More Information...

- www.powerstudies.com
- Contact us!
- Bob Fuhr

Ph 253-639-8535
Fax 253-639-8685
22443 SE 240th St
Maple Valley, WA
fuhr@powerstudies.com

41