How to Design Multi-kW Converters for Electric Vehicles

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Part 3:	Power Factor and Harmonic Currents
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Part 5:	The Phase Shifted Full Bridge
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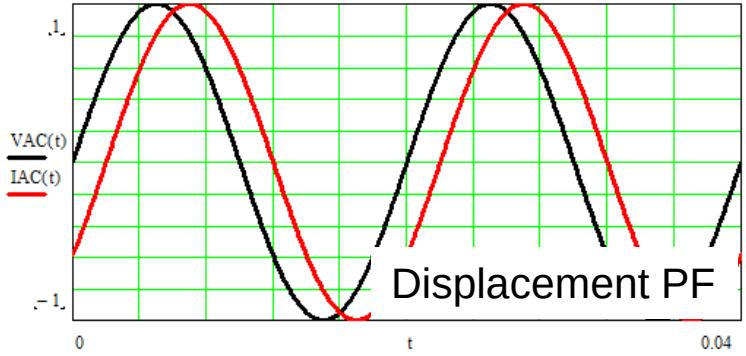
Displacement Power Factor

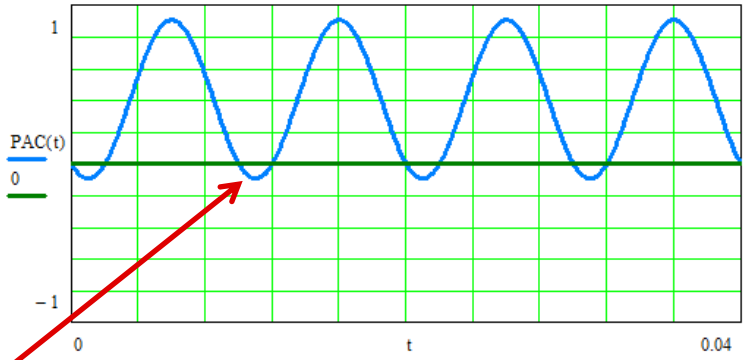
$$PF = \cos\theta$$

- Displacement PF
  - Caused by Reactive loads, eg AC motors
  - not normally significant in SMPS
  - X-Capacitors for EMI filtering
  - PF is cos(θ) – cosine of angle between current and voltage, about 0.8 here

- Supply Utilities don't like this because power flows in both directions – but they get paid only for the power delivered to the user !

- Current and Voltage are Sinusoids
  - No Harmonic distortion





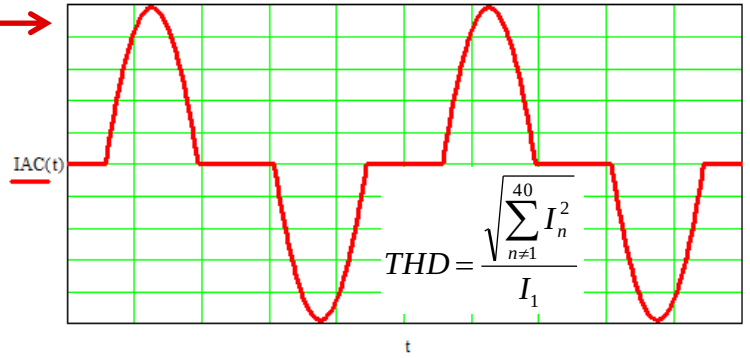
P_AC(t)

Distortion Power Factor

- Non Sinusoidal input current
  - Significant Harmonic content
- Harmonic Currents are Controlled
  - By IEC61000-3-2, Up to 40th Harmonic
- PFC stage corrects distortion power factor

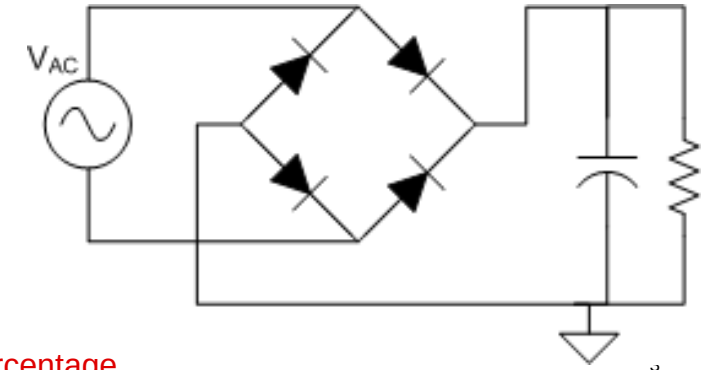
Distortion PF

$$PF = \sqrt{\frac{1}{1+THD^2}}$$



- PF is the product of the Displacement and Distortion power factors

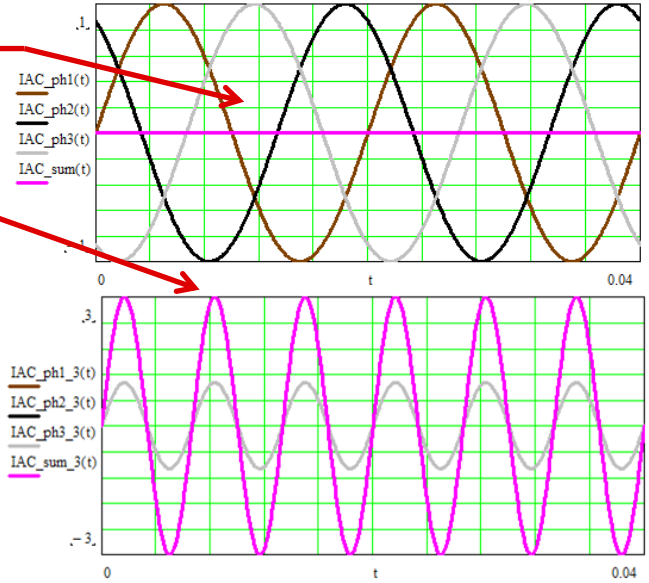
$$PF = \sqrt{\frac{1}{1+THD^2}} * \cos\theta$$



Here THD (Total Harmonic Distortion) is expressed as a number not a percentage.

3 Phase Harmonic currents

- In a 3 Phase Power Distribution System
- Fundamental and most harmonic currents sum to zero in the neutral conductor (purple)



- ‘Triplen’ Harmonics add in Neutral
  - 3rd, 9th, 15th, etc (purple)
  - Cause heating, Large Neutral to Ground voltages
  - Other ‘bad’ effects
  - (all three IAC traces lie on top of each other on this graph)
- PFC is required to reduce these ‘bad’ effects
- Both Even and Odd Harmonics are regulated for Class A equipment (eg OBC)

Harmonics, IEC61000-3-2

- IEC61000-3-2 "Electromagnetic compatibility (EMC) - Part 3-2: Limits - Limits for harmonic current emissions (equipment input current ≤ 16 A per phase)
- Class A, Class B, Class C and Class D
  - Class A, applicable for On Board Chargers

Even Harmonics	
Harmonic	**Max. permissible harmonic current**
2	1.08
4	0.43
6	0.3
8 ≤ n ≤ 40	0.23*8/n

Odd Harmonics	
Harmonic	**Max. permissible harmonic current**
n	A
3	2.3
5	1.4
7	0.77
9	0.4
11	0.33
13	0.21
13 ≤ n ≤ 39	0.51*8/n

Guidelines to this standard at:
http://www.epsma.org/pdf/PFC%20Guide_November%202010.pdf

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Thank You

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