The AccuSine Solution :

The New Age of Harmonic Control and Power Factor Correction

Merlin Gerin
Square D
Telemecanique

Schneider Electric
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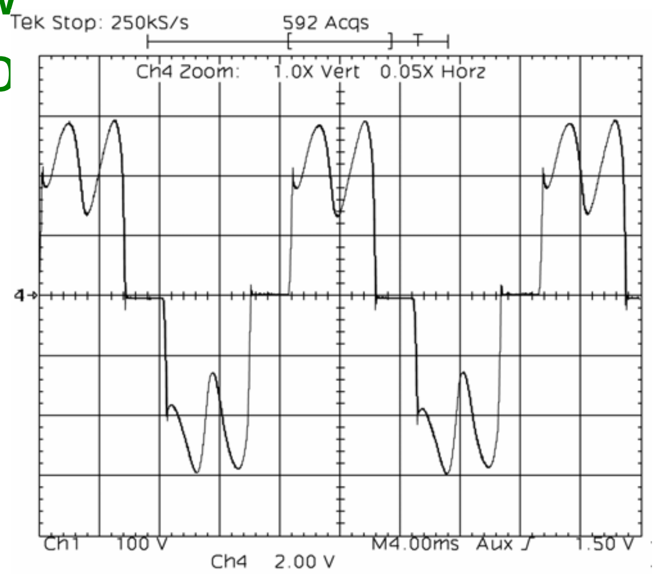
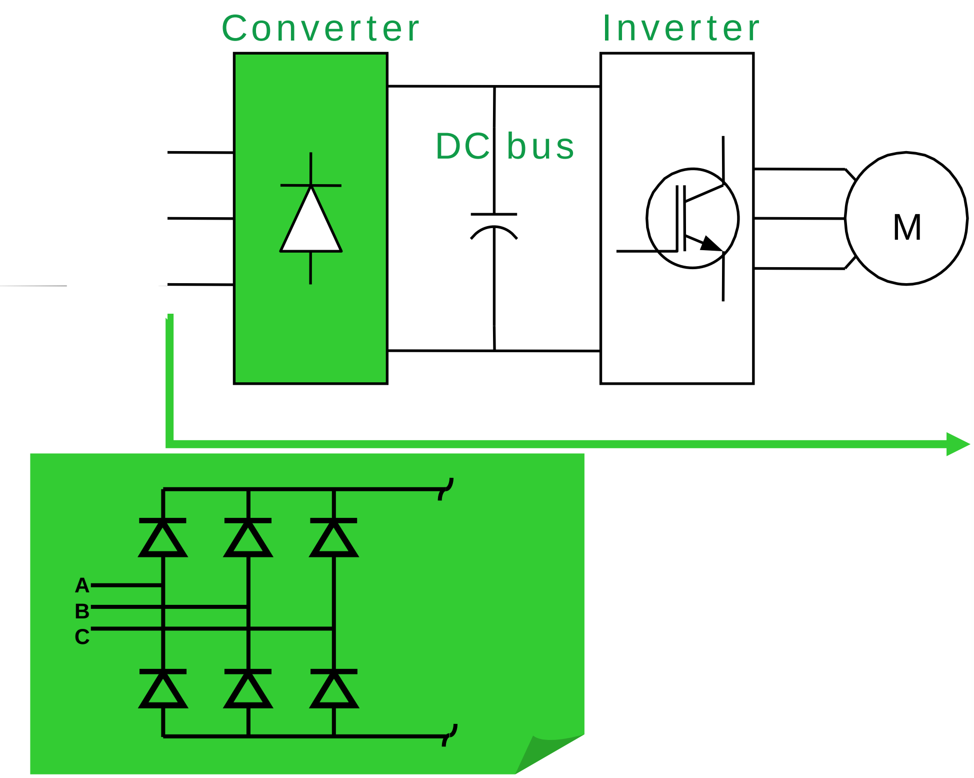
Harmonics: Fundamentals

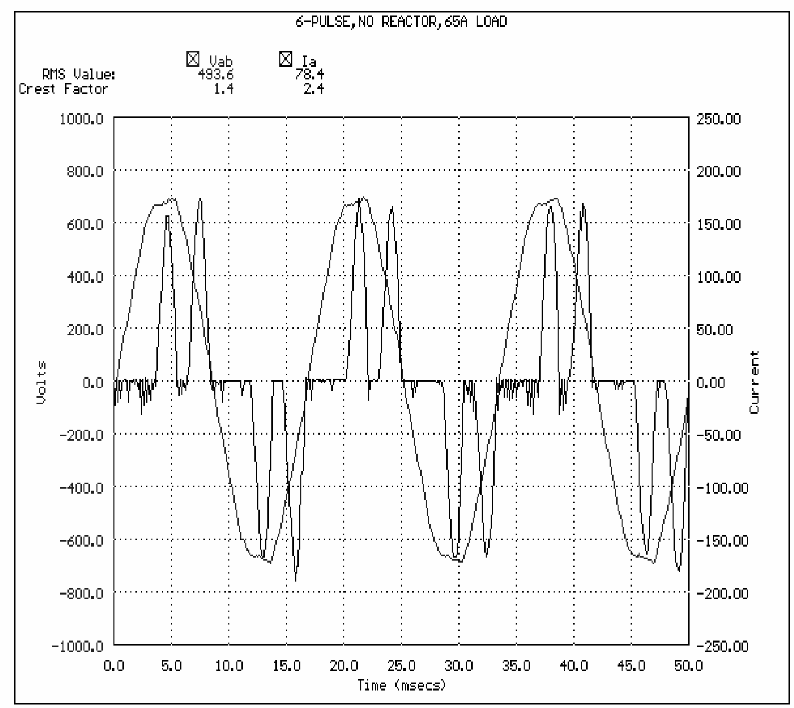
- Definition:
  Harmonics are integer multiples of the fundamental frequency that, when added together, result in a distorted waveform
- Where do Harmonics come from?
  Nonlinear devices draw distorted waveforms to operate, waveforms are comprised of harmonics from the source



Harmonic Basics

- Nonlinear loads draw nonlinear current from source





Creating a Square Wave

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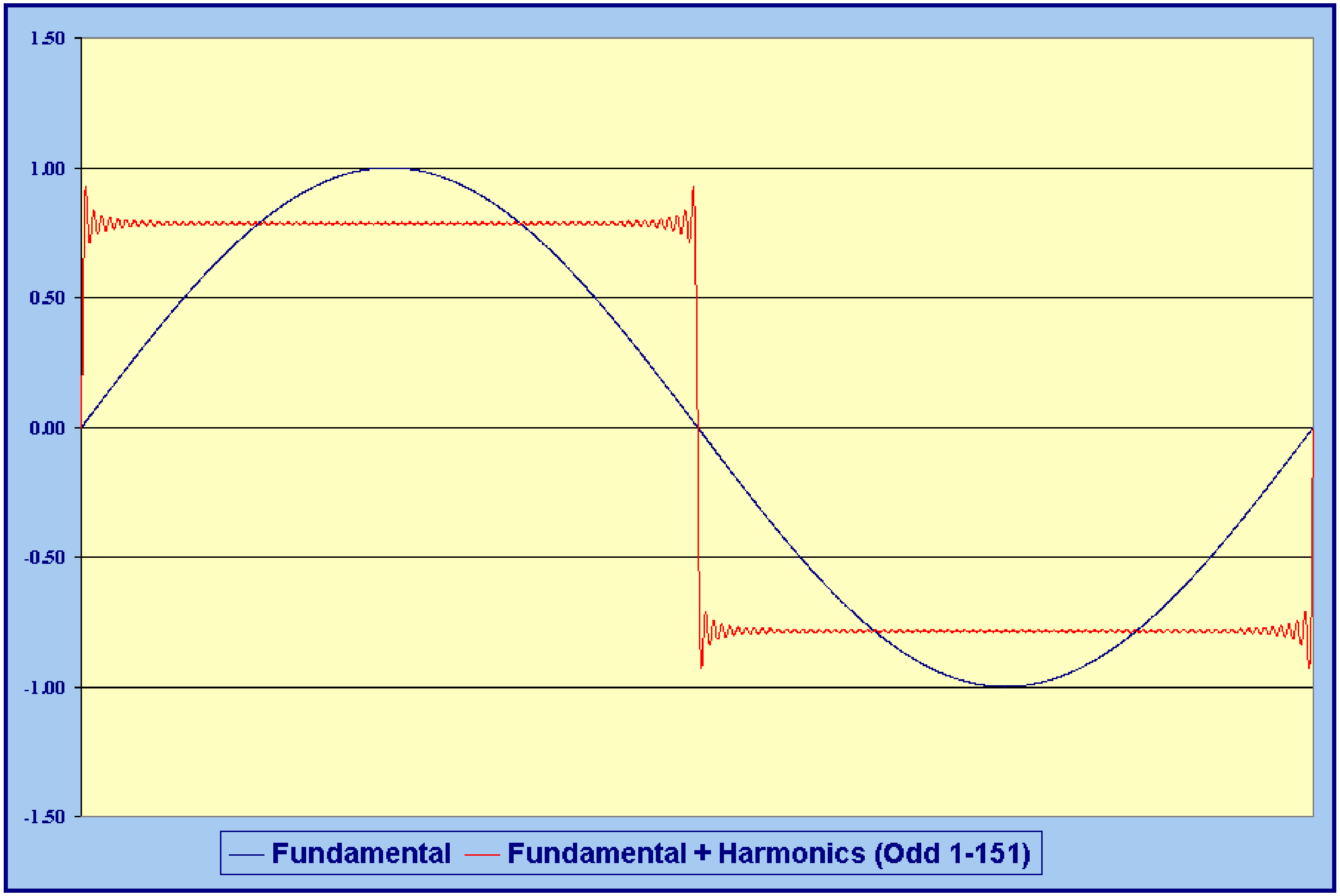

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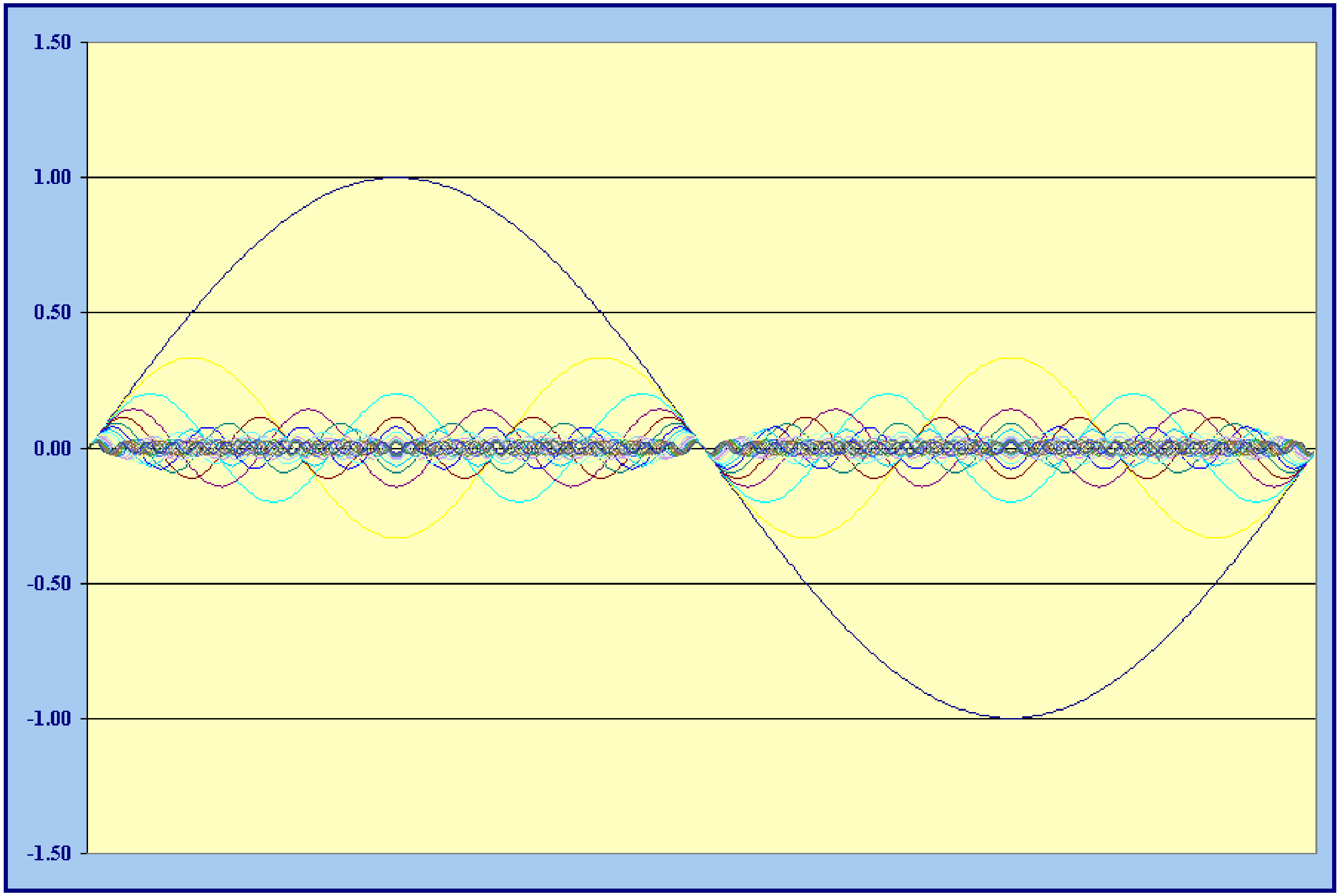
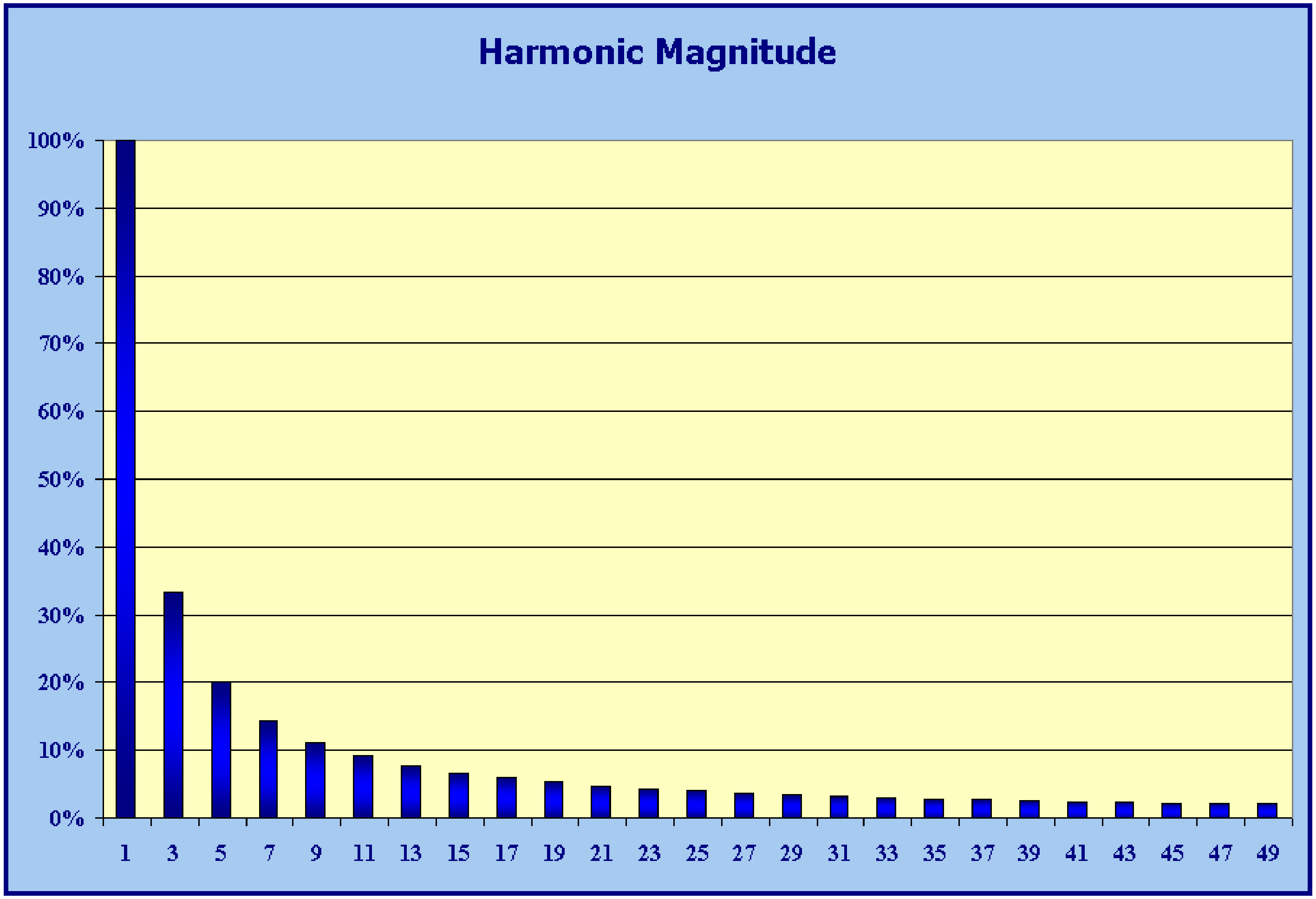


Creating a Square Wave



Creating a Square Wave

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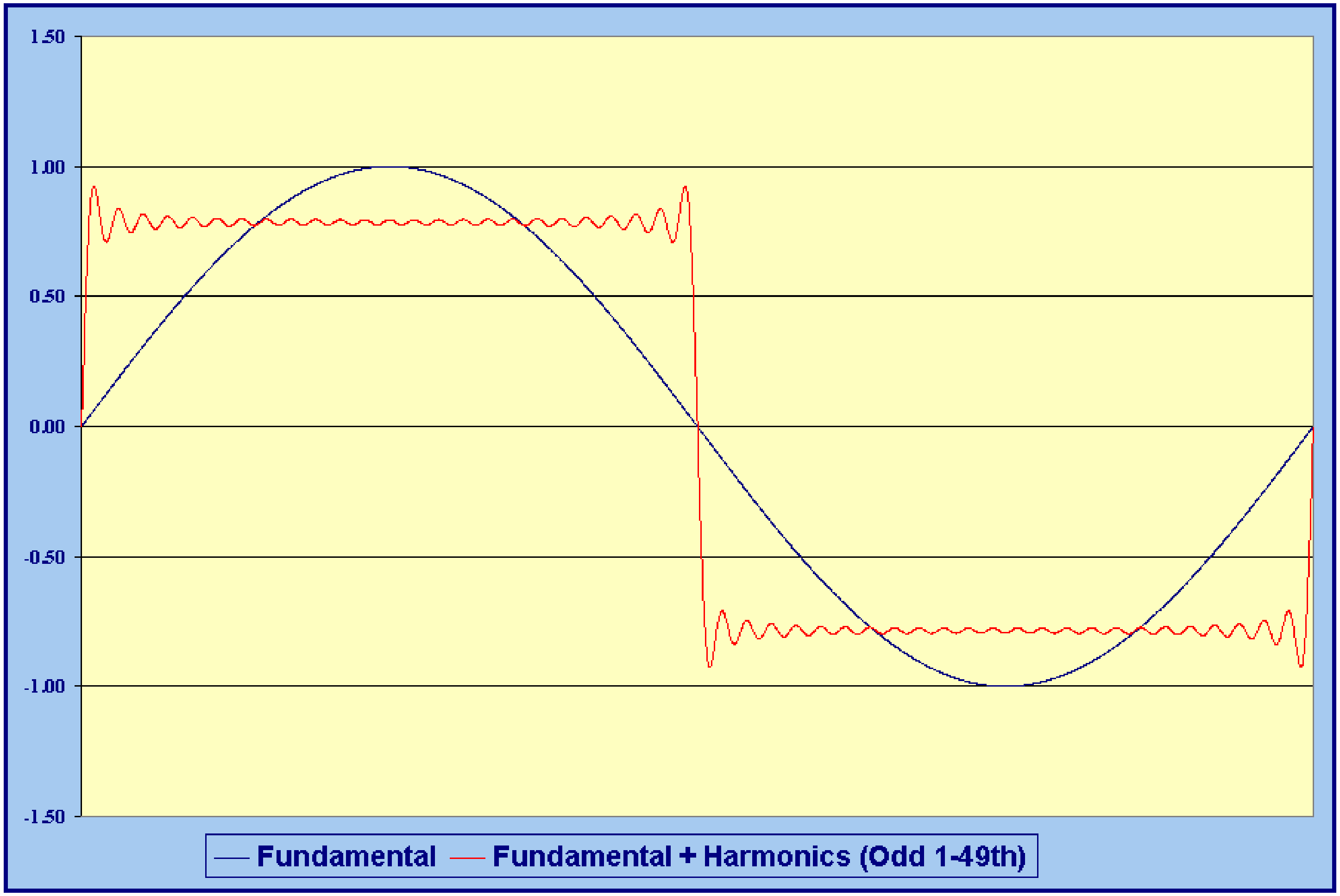

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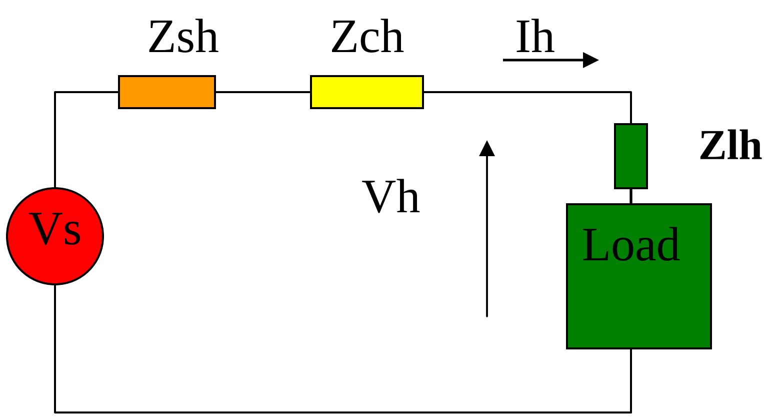
Harmonics in electrical systems

- **Current Distortion**
  - ⇨Detrimental to Electrical Distribution Systems
  - ⇨Heating
  - ⇨Limit set by IEEE 519 Table 10.3
- **Voltage Distortion**
  - ⇨Detrimental to Connected Load
  - ⇨System communication errors
  - ⇨Power supply failures
  - ⇨Limit set by IEEE 519 Table 11.1

Harmonics: Fundamentals (cont.)



Vh = Harmonic voltage

Ih = Harmonic current

Zsh = Source impedance for harmonic current

Zch = Cable impedance for harmonic current

Zlh = Impedance of nonlinear load

$$Vh = Ih * (Zsh + Zch)$$

- Harmonic voltages (Vn):
  - ⇨ Ohm’s Law applies: Vn = In * Zn
  - ⇨ To reduce Vh: Reduce system impedance (Zsh & Zch) or reduce current (Ih)

IEEE 519 Voltage Limits

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Section 11 Recommended Practices for Utilities

Table 11.1

Voltage Distortion Limits

Bus Voltage at PCC	Individual Voltage Distortion (%)	Total Voltage Distortion THD (%)
69kV and below	3.0	5.0
69.001kV through 161kV	1.5	2.5
161.001kV and above	1.0	1.5

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IEEE519-1992 only defines TDD

- **Section 10** Recommended Practices for Individual Consumers
- TDD (Total Demand Distortion) defined as harmonic current level measured against the system MAX DEMAND LOAD Current

IEEE 519-1992, Table 10.3

Isc/Iload	<11	11<=h<17	17<=h<23	23<=h<35	h>=35	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%	0.2%	1.0%	15.0%
>1000	15.0%	7.0%	6.0%	2.5%	1.4%	20.0%

Isc = short circuit current capacity of source
Iload = demand load current

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TDD and THD (I) are not the same

- THD (I) = $\frac{\text{RMS Harmonic Current}}{\text{RMS Fundamental}}$
- TDD = $\frac{\text{Root-Sum-Square Harmonic Current Distortion}}{\text{Max Demand Load Current (15 or 30 min)}}$

	Measured				
	Total I, rms	Fund I, rms	Harm I, rms	THD(I)	TDD
Full load	936.68	936.00	35.57	3.8%	3.8%
	836.70	836.00	34.28	4.1%	3.7%
	767.68	767.00	32.21	4.2%	3.4%
	592.63	592.00	27.23	4.6%	2.9%
	424.53	424.00	21.20	5.0%	2.3%
	246.58	246.00	16.97	6.9%	1.8%
	111.80	111.00	13.32	12.0%	1.4%

As load decreases, TDD decreases while THD(I) increases.

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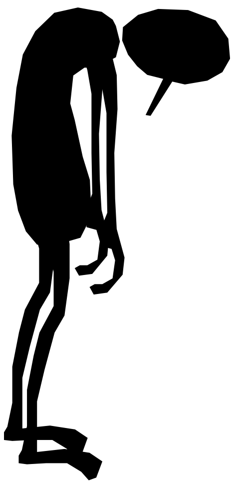
Harmonics in electrical systems increase business operating costs…….



- Increased system downtime
- Increased maintenance
- Lower Quality and Efficiency
- Reduced system capacity

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Controlling harmonics: Which solution is right for your facility?

- Inductors/transformers
- Traditional passive filters
- Multi-pulse drives
- Clean products
- Active harmonic control with AccuSine

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Inductors/Transformers to Filter Harmonics

- Pros:
  - ⇨ Inexpensive & reliable
  - ⇨ 1st Z yields big TDD reduction
  - ⇨ Complimentary to active harmonic control
- Cons:
  - ⇨ Reduction dependent on source Z%

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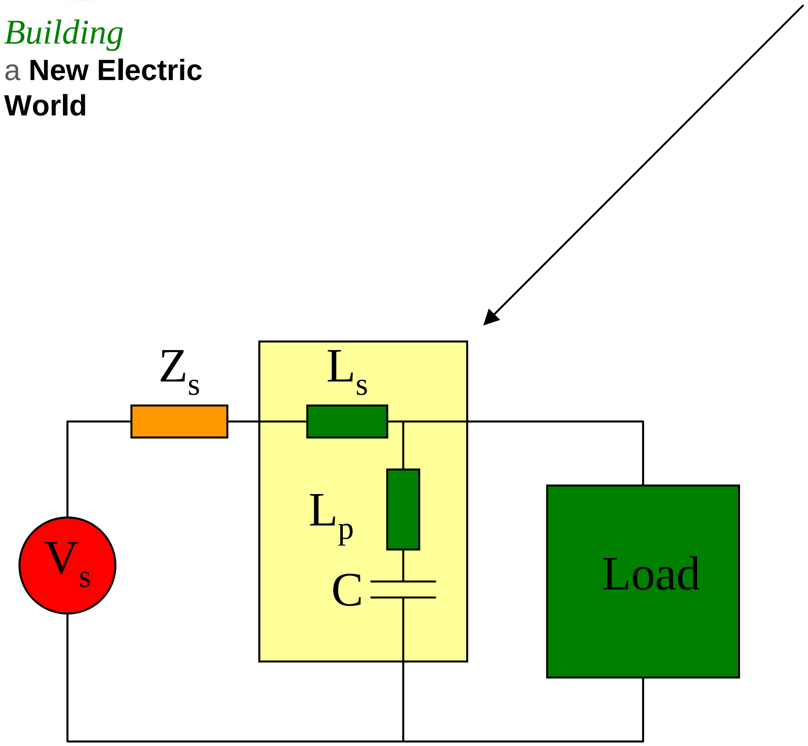
5th Harmonic Filter



- Inductor (L_p) and Capacitor (C) provide low impedance source for a single frequency (5^{th})
    - Must add more tuned filters to filter more frequencies
- Inductor L_s required to detune filter from electrical system and other filters
    - If L_s not present, filter is sink for all 5^{th} harmonics in system
    - If L_s not present, resonance with other tuned filters probable
- Injects leading reactive current (KVAR) at all times – may not need/want
- Achieves about 20% TDD

Broadband Filters

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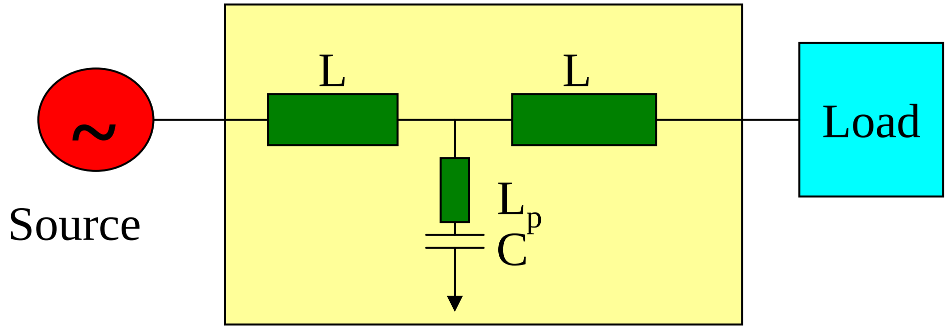

Mitigates up to 13th order
- Each inductor (L) > 8% impedance
  - V drops ~ 16% at load
  - Trapezoidal voltage to load
    - Can only be used on diode converters
  - Prevents fast current changes (only good for centrifugal loads)

- Capacitor (C) designed to boost V at load to proper level (injects leading VARs)
- Physically large
- High heat losses (>5%)
- Series device

Multi-Pulse Drives Description

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12 Pulse Rectifier

- Two rectifier sections
- Phase shifted by 30°

18 Pulse Rectifier

- Three rectifier sections
- Phase shifted by 20°

Multi-Pulse Drives Description

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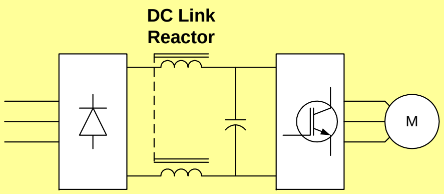
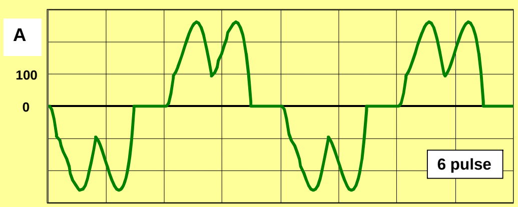
- **6-Pulse converter**

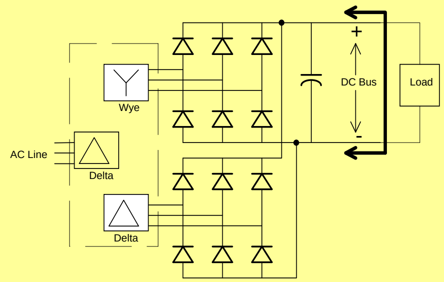


“C-less” or 3% reactance min (if included); small footprint, simplified cabling

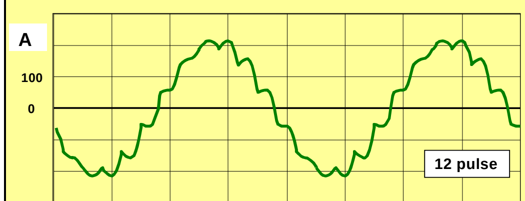


Current waveform distorted
TDD 30% to 40% with 3% reactor (depending on network impedance)

- **12-Pulse converter**

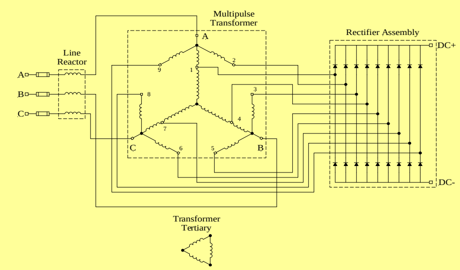


Externally mounted 3 winding transformer; more wire and cabling; complicated

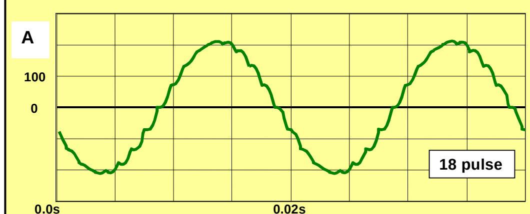


Current slightly distorted
TDD 8% to 15% (depending on network impedance)

- **18-Pulse converter**



Large footprint, more steel & copper (losses)



Current wave form good
TDD 5% to 7% (depending on network impedance)

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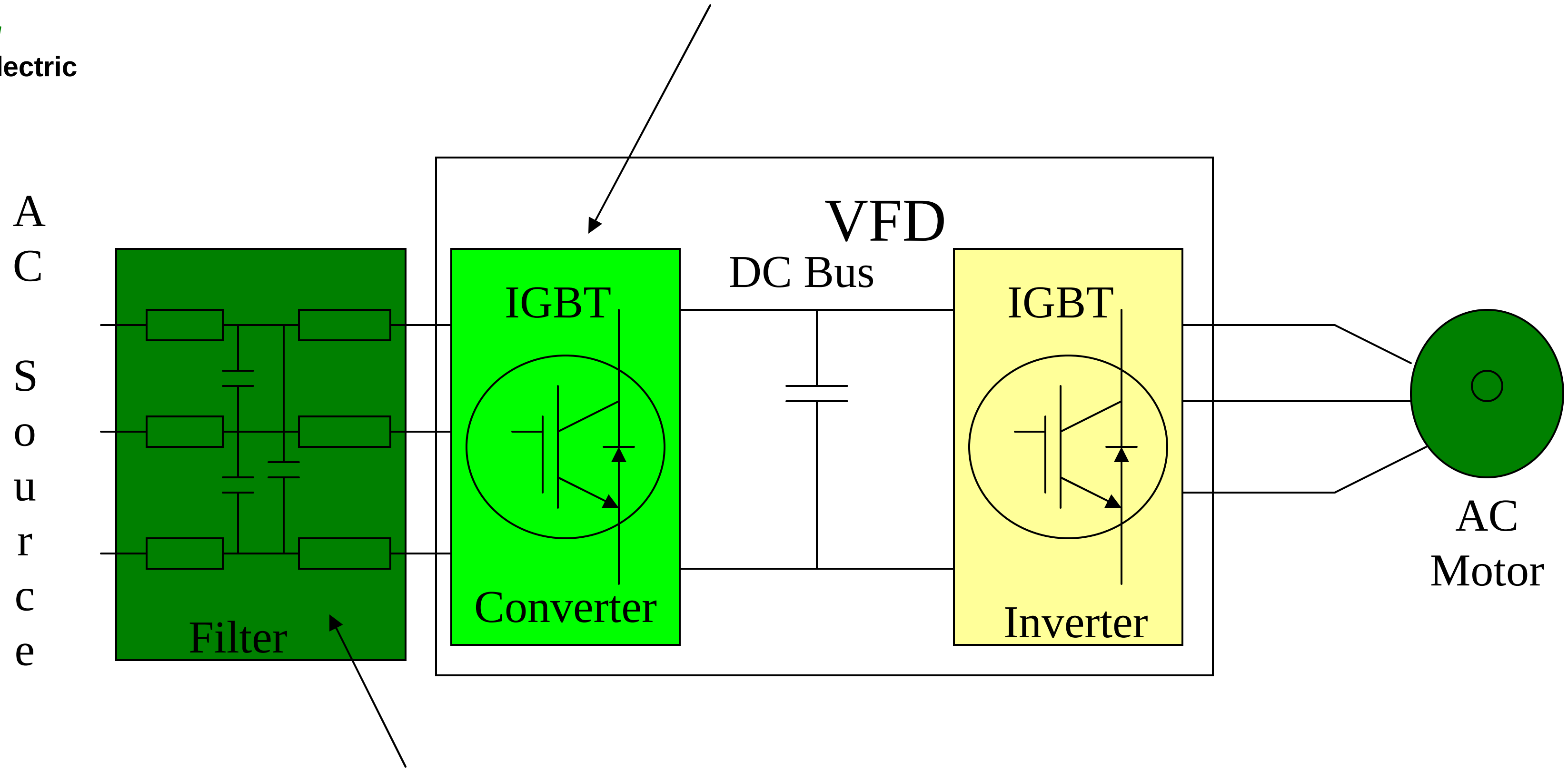
Active Front End Converter



Required to limit
line THDv

How AccuSine Works

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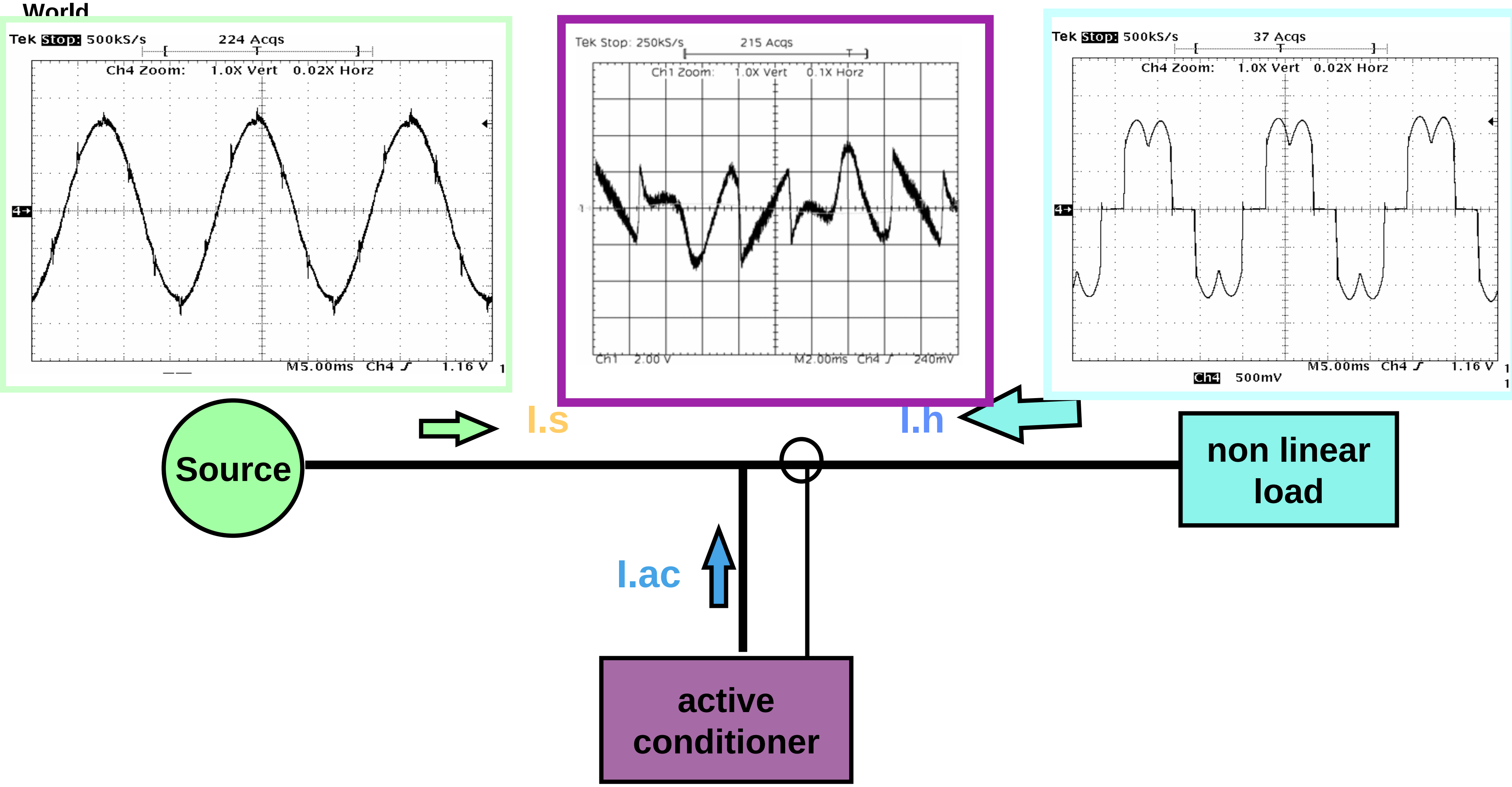

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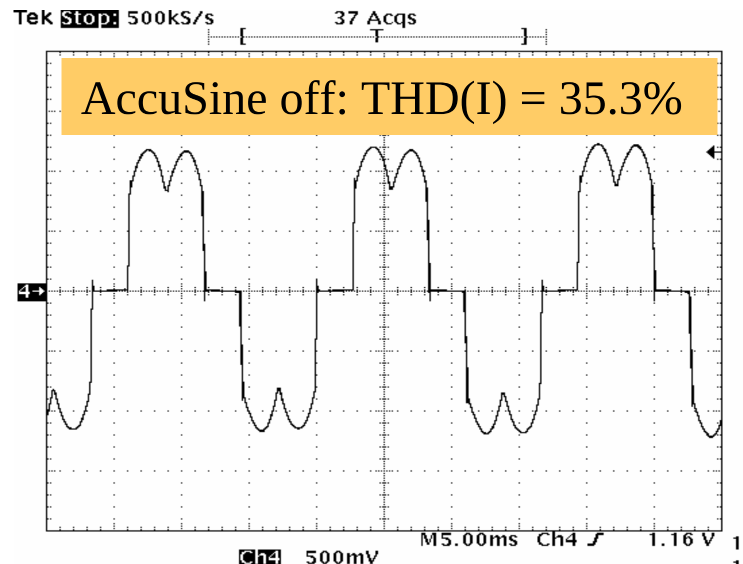
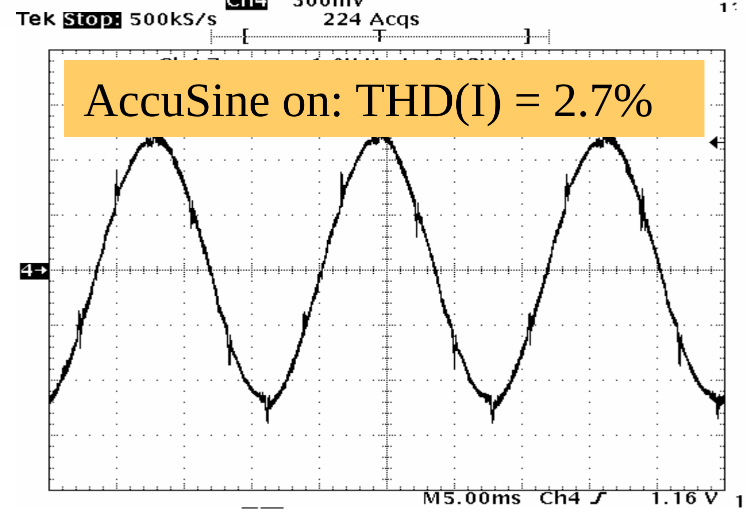
An Example of AccuSine Harmonic Performance - 150 HP DC drive

Order	AS off % I fund	AS on % I fund
Fund	100.000%	100.000%
3	0.038%	0.478%
5	31.660%	0.674%
7	11.480%	0.679%
9	0.435%	0.297%
11	7.068%	0.710%
13	4.267%	0.521%
15	0.367%	0.052%
17	3.438%	0.464%
19	2.904%	0.639%
21	0.284%	0.263%
23	2.042%	0.409%
25	2.177%	0.489%
27	0.293%	0.170%
29	1.238%	0.397%
31	1.740%	0.243%
33	0.261%	0.325%
35	0.800%	0.279%
37	1.420%	0.815%
39	0.282%	0.240%
41	0.588%	0.120%
43	1.281%	0.337%
45	0.259%	0.347%
47	0.427%	0.769%
49	1.348%	0.590%
% THD(I)	35.28%	2.67%





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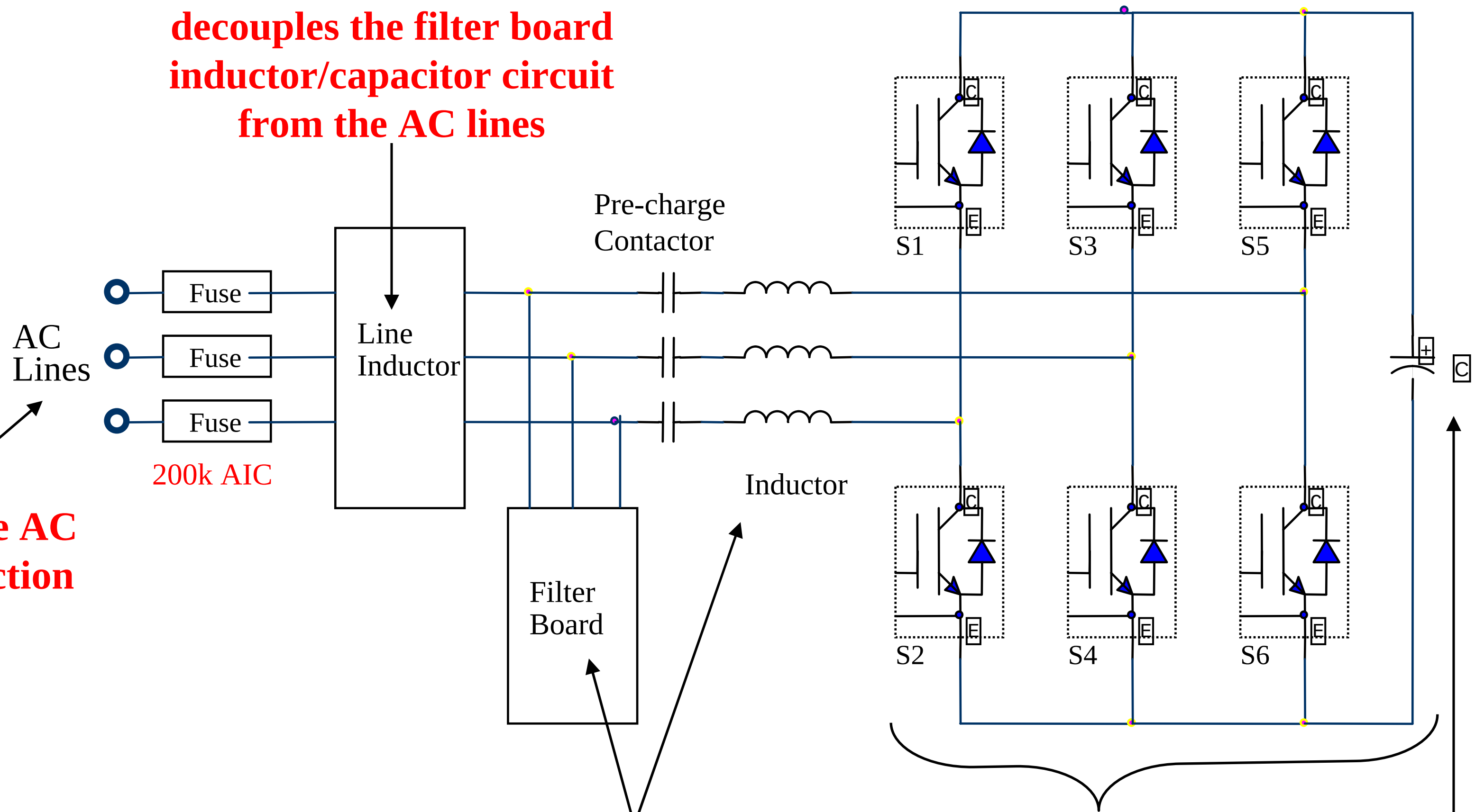
Sophisticated control and protection: AccuSine Power Diagram

decouples the filter board inductor/capacitor circuit from the AC lines



three phase AC line connection

remove the carrier frequency from the current waveform sent into the AC lines.

IGBTs* manage the power flow to/from the *DC bus caps

Product Package

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- Standard (UL only)
- Three sizes
- Enclosed – IP30 (NEMA 1)
  - ⇨50 amp – 52”(1321mm) x 21”(533mm) x 19”(483mm)
    - Weight – 250#(114 Kg)
  - ⇨100 amp – 69”(1753mm) x 21”(533mm) x 19”(483mm)
    - Weight – 350#(159 Kg)
  - ⇨300 amp – 75”(1905mm) x 32”(813mm) x 20”(508mm)
    - Weight – 775#(352 Kg)
- Chassis – IP20
- Wall mount – 50 & 100 amp
- Free standing – 300 amp with disconnect

AccuSine Selection Data

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Rated Electrical System Load		
AccuSine Size	**Total Losses (W)**	**Real current (amps)**
50A	1800	6.50
100A	2850	10.28
300A	8500	30.67

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Product Re-packaging

- MCC Packaging
  - ⇨50 & 100 amp models only
  - ⇨Several vendors have it (NA)
  - ⇨Requires one vertical 20” x 20” section
  - ⇨Includes circuit breaker

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AccuSine: the best choice for harmonic control

- One AccuSine system/group of loads
- TDD is total system capacity to handle harmonics
  - ⇨ Includes linear loads
- Less space than other filtering solutions
- Lower cost when applied on multiple loads

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Web Based Selection Tool

- http://www.squaredleantools.com/

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Add Load or Drive

Type: VFD PWM with diode rectifier

QTY	DPF (Cos φ)	Size of Load	Type of Load	# of Pulses	Installed Inductance	z	Maximum Load Factor*
	.950	KW	CT	6	Line Reactor	3.0 %	.90

VT applications are centrifugal pump and fan loads. All other applications are considered CT (constant torque) loads.

Add

Summary of Loads

Item	QTY	Type	DPF (Cos φ)	Size of Load	Type of Load	# of Pulses	Installed Inductance	z	Maximum Load Factor*		
No Additional Loads or Drives have been Added.											

* **Maximum Load Factor** is the maximum load that the device will attain in per unit of rating. For instance, most centrifugal loads are selected to use at most 80% of the drive/motor capacity. Enter .80 for 80%. However, most constant torque applications (i.e. conveyors, drills, presses, etc.) will use 100% of the drive/motor capacity. Enter 1.0 for 100%.

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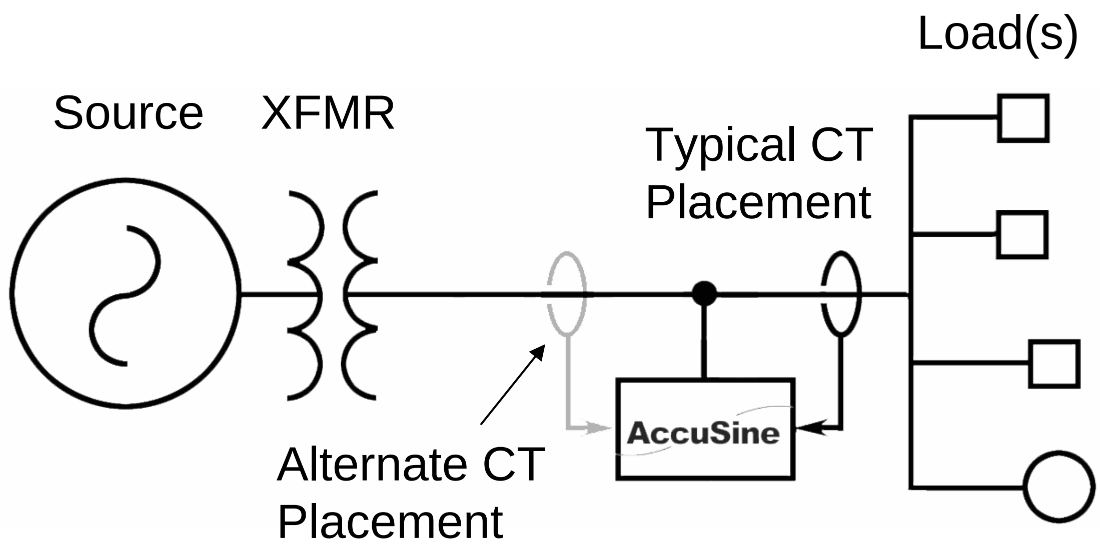
AccuSine Installation Flexibility



- Can easily add more capacity when required to meet facility expansion needs
- Multiple units operate in parallel so additional units can be installed using the same CT's

AccuSine Sizing Examples

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- A 125 HP variable torque 6-pulse VFD with 3% LR
  - ⇨ Required AHF filtering capability = 47.5 amperes
- Two 125 HP VT 6-pulse VFD w/3% LR
  - ⇨ Required AHF size = 84.4 amps
- Three 125 HP VT 6-pulse VFD w/3% LR
  - ⇨ Required AHF size = 113.5 amps
- Six 125 HP VT VFD w/3% LR
  - ⇨ Required AHF size = 157.6 amps
  - ⇨ (not 6 x 47.5 = 285 amps)

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AccuSine is economically the best solution when…..

- Applied on bus with multiple loads, or at PCC with utility
- Considering the total solution cost
  - ⇨ Application engineering
  - ⇨ Hardware
  - ⇨ Installation
  - ⇨ Downtime

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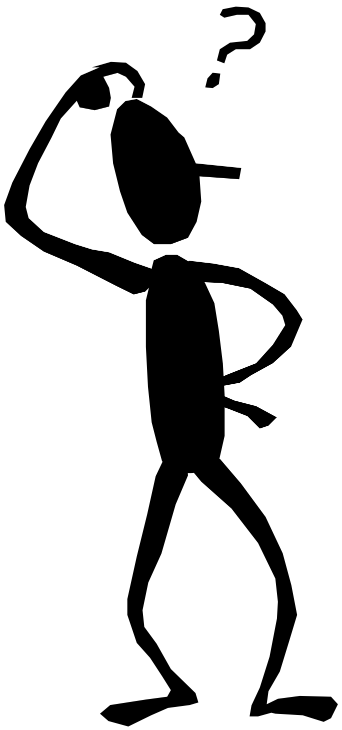
Thank You.

Resources:



www.accusine.com or
www.reactivar.com

1-888-squared

Technical Support:

Factory
503-587-5200 X206 or x261

PQC Group – Toronto

905-364-3009